Appendix B

OIL SPILL MODELING

This page intentionally left blank.

Appendix B-1

RESULTS FROM UNOCAL SPILL MODELING APPLICABLE TO THE SHELL MARINE TERMINAL

This page intentionally left blank.

Appendix B-1
Results From Unocal Oil Spill Modeling
Applicable to the Shell Marine Terminal

Background of Previous Spill Modeling

In 1994, the EIR prepared for the Consideration of a New Lease for the Unocal Marine Terminal (now ConocoPhillips, Rodeo), extensively analyzed the potential consequences of oil spills on the environment. No previous Bay-wide area oil modeling was available at that time. The analysis was conducted to estimate the probability of spills and fate of the spilled material (e.g., where the oil would go if a spill occurred) for transit lanes within the greater Bay Area as well as the outer coast. Modeling specific to the Unocal Marine Terminal also was conducted. Spill trajectory modeling was used to evaluate (1) the effectiveness of existing response capabilities of Unocal and supporting Bay Area oil spill response organizations, (2) impacts on future response capability (since the Unocal lease was to be for a 40-year period), and (3) assessment of impacts of spills on biological, water quality, commercial and recreational fisheries, shoreline uses, recreational users, and visual resources.

Modeling included a combination of the hydrodynamics of tidal and current conditions throughout the Bay, into Carquinez Strait, and outer coast combined with a complex program of simulated oil spills. These data were overlain via GIS with mapped sensitive resources that occur to help determine the potential for impacts and thus, determine mitigation to be applied. The hydrodynamic simulation modeling was conducted by the Center for Environmental and Water Resources Engineering of the University of California at Davis, California, and the oil spill modeling was conducted by Ecological Consulting, Inc., Portland, Oregon.

Resource mapping was undertaken by the CSLC, the Center for Environmental Design Research at the University of California at Berkeley, Ecological Consulting, Inc., and Chambers Group, Inc., Irvine. In all cases, resource mapping involved a map-based delineation of relevant features of ecological interest or related importance, and the conversion of those features to digital form. Both the CSLC and Chambers Group developed and digitized resources maps from standard base maps (USGS 1:24,000 quadrangles). As a separate effort, the CSLC digitized the entire California and San Francisco Bay shoreline at 1:24,000 scale. Resource maps were merged with this standard shoreline to ensure geographic consistency across data sets.

Oil spill model results were combined with the resources data base to produce a GIS based, synthesized map coverage that displayed the interaction between oil spill scenarios and vulnerable resources, over time, to the maximum extent of the spread of the oil. These coverages were used in the analysis of potential impacts in the EIR. The areal extent of impact was able to be produced in both mapped and tabular formats. Maps showed a resource or grouping of resources with either probabilistic or scenario oil spill spread information overlain. Tables were produced, showing the amount of a resource that was affected by modeling in either miles (for shoreline) or acres (areal extent, such as a wetland). In this manner, potential impacts could be both visually assessed and quantified.

Modeling

Ecological Consulting used the modeling technique, OSRISK, developed by the National Oceanographic and Atmospheric Administration (NOAA) Hazardous Materials Modeling Group to describe this process. A spill is represented as a cluster of independently moving points (called Lagrangian elements), each one representing a fraction of the entire spill volume. The basic model output for a given oil spill scenario is a tracking of the position of the Lagrangian elements at 30-minute intervals within the Bay. The area affected by an oil spill varies greatly with the volume of the spill, age of the spill, and the wind and current conditions that prevail during the course of the spill. OSRISK simulated the process of spreading using random diffusion factors which were based on the real hydrodynamic modeling incorporated by the data from the University of California at Davis.

Because both crude and refined petroleum products typically contain a substantial portion of volatile compounds, the volume of a spilled product that remains in the environment will decrease with time. Most products are composed of a number of fractions that vary greatly in terms of their volatility. Light, volatile fractions usually disappear within hours, while heavier, tarlike fractions may persist for years. The model OSRISK describes this process. Spilled volume are divided into component fractions, each component having an estimated half-life. At the time when a Lagrangian element is released, it is assigned to one of the oil fractions. The number of Lagrangian elements assigned to each fraction is proportional to the relative volume of that volatile compound and has a specific probability of disappearing.

A wide range of crude oils and refined products are shipped into and out of the Bay, as such crude oil and products were divided into two general classes: light products and crude oil. Simulations of light product spills were based on the characteristics of kerosene, a typical light refined product. This type of product volatilizes relatively rapidly, and little remains within 24 to 48 hours after a spill occurs. Crude oils also vary widely in their composition, but typically contain a substantial amount of highly persistent tar-like compounds. While the lighter fractions of a crude oil spill may disappear over a period of several days, the remaining heavier fractions may last from several weeks to several months, floating at or near the water surface. Initially, these heavier fractions may emulsify with sea water to form a substance called mousse. In this state, the effective volume of oil can actually increase in spite of the evaporation of the more volatile components. The remaining oil may eventually form into highly persistent tarballs or mats. All of these processes depend not only on the composition of the spilled crude oil, but also on weather conditions and sea state. Therefore, crude oil was modeled as persistent, and each Lagrangian element was tracked until it beached or moved outside the model domain. Because spills within the Bay can be deposited on land within a few days, they were tracked by the model for up to two weeks. Because spills along the tanker routes outside the Bay can take several weeks to make landfall, those model runs were tracked for up to 30 days.

Probablistic Analysis

Probablistic/conditional modeling was used to estimate the likelihood that a spill would contact a given region or resource at any time during the life of the proposed Unocal lease. This took into account the likelihood that a spill would occur in a particular location, the probability that a given type of material would be spilled, the probability that a spill would be of a particular volume and the likelihood that a spill would occur at a particular time of the year. The modeling showed the general flow of high, medium and light volumes of oil during three seasonal variations reaching the shoreline in the Bay.

Of pertinence to the Shell Terminal is the fact that Unocal tankering and those tankers bound for the Shell Terminal both follow the same established tanker lanes at least up to the point where Unocal-bound tankers pull out of the main lanes to the Unocal (ConocoPhillips) facility. The modeling found that oil spills along the route used by these tankers through the Bay predominantly affect waters of the ship channel, where they are moved back and forth with tidal currents. This effect is greatest in the north part of San Francisco Bay and in San Pablo Bay. Closer to the Golden Gate, spills tend to be flushed from the Bay on ebb tides. Most waters within about 2 km of the ship channel are subject to at least a 30 percent change of contact from crude oil spills (slightly less for product spills). The likelihood of contact declines with distance from the ship channel, especially over broad expanses of shallow water and mudflats. Land subject to the greatest chance of contact is in Carquinez Strait, Mare Island, along the southern shore of San Pablo Bay, from Point San Pablo to Point Richmond, the eastern shore of the Tiburon Peninsula, and Angel Island. The likelihood of moderate or heavy oiling follows the same pattern, with the greatest chance found in deeper waters of the ship channel. Point San Pablo and Angel Island are each subject to a 12 to 17.5 percent chance of moderate oiling from a crude oil spill and up to a 3 percent chance of heavy oiling.

Scenario Modeling

The Unocal EIR modeling included the display of 14 individual, various-sized Bay scenarios representing spills of crude and product. These spills were meant to examine the severity of potential impacts on sensitive resources, and were based on reasonable worst-case oil spill scenarios. The quantity of oil released in each scenario was determined after considering historical spill sizes and data on engineering and design of tankers and transfer facilities. The time-course of movement and spread of the oil was then modeled under specified currents and winds. Each spill scenario was constructed from the output of 150 to 1,000 model runs (number of runs determined by the quantity of oil released), each providing the time-course of movement of a dimensionless point (Lagrangian element) representing a portion of the oil released.

Scenarios included spills in the immediate area of the Unocal Terminal, and scenarios for spills in the San Francisco Bay nearby traffic lanes. *Of note, those scenarios within the Bay or coastal traffic lanes can be applied to any assessment of impacts interested in consideration of the oil spread from a tanker spill.*

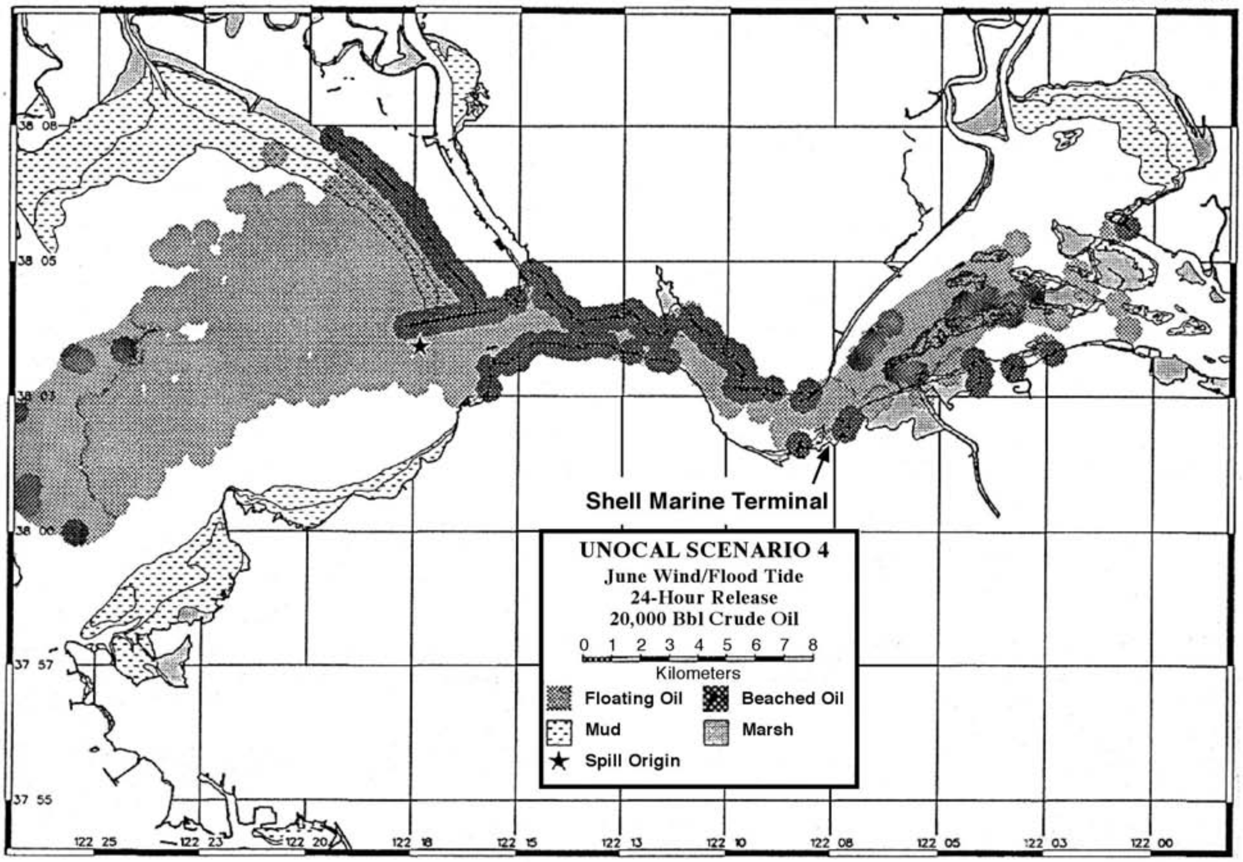
Twelve scenarios were in the San Francisco Bay/San Pablo Bay/Carqinez Strait areas, and included: 1,000 bbl spills launched at the Unocal Terminal of crude oil under ebb tide and flood tide conditions (Scenarios 1 and 2); 20,000 bbl spills of crude oil launched from the shipping lane northwest of the Unocal Terminal under ebb tide and flood tide (Scenarios 3 and 4); 1,000 bbl spills of crude oil launched from the shipping lane at the east end of Carquinez Strait under ebb and flood tides (Scenarios 5 and 6); 500 bbl product spills released from the Unocal Marine Terminal under flood and ebb tides (Scenarios 7 and 8); 100,000 bbl spills of crude oil released over a 24-hour period in the tanker lane near Alcatraz Island about 5 km southwest of Hunters Point during flood tide and ebb tide conditions (Scenarios 9 and 10); and two scenarios run as representative of 100,000 bbl spills in the outer coast shipping lanes. All models were run to display the maximum areal extent of oiling. Two seasonal variations were run for each scenario, representative of the variable wind conditions in the Bay. The time-course of movement and spread of the oil was then modeled under specified winds and currents to the maximum oil spread.

<u>Scenarios Applicable to the Shell Terminal</u>

Three of the modeled scenarios from the Unocal EIR (Bay Scenarios 4, 5, and 6, in Figures 4.2-5, 4.2-6, and 4.2-7, respectively), are considered applicable to the Shell Terminal as an aid in determining the potential spread of oil spills that could originate from the established tanker route near Carquinez Strait. Even though the points of release for these scenarios are outside of Carquinez Strait, the scenarios show that that tidal conditions are such that oil can easily spread and beach in the area of the Shell Terminal. The Unocal EIR results are also consistent with those provided in the EIR for the Shore Terminals LLC marine terminal lease renewal (Chambers Group 2004) and Shore Terminals' own spill model and trajectory analysis included in their Spill Response Plan and included herein as Appendix B-2 (reproduced from the Shore Terminals EIR), and the Clean Bay trajectory analysis contained in the Wickland Oil Martinez 1998 Application (see Appendix B-3). All three analyses are consistent in that they show widespread oiling in Carquinez Strait. Thus, no new oil spill modeling has been conducted specific to the Shell Terminal, also located in Carquinez Strait. The Shell Terminal's Oil Spill Response Plan contains a determination of worst case discharge of oil and a tabular format of sensitive areas that could be oiled from a spill. The sensitive areas match those depicted in the other model runs discussed herein. The Shell Terminal is located approximately 1.5 miles west of the Shore Terminal. *For the purposes of the analysis in this EIR, it was assumed that spills of oil at or near the Shell Terminal have the potential to contact all areas in Carquinez Strait and into San Pablo Bay.*

The descriptions of Bay Scenarios 4, 5, and 6 are provided below Figures 4.2-5, 4.2-6, and 4.2-7, respectively.

8413-D SHELL 08-06

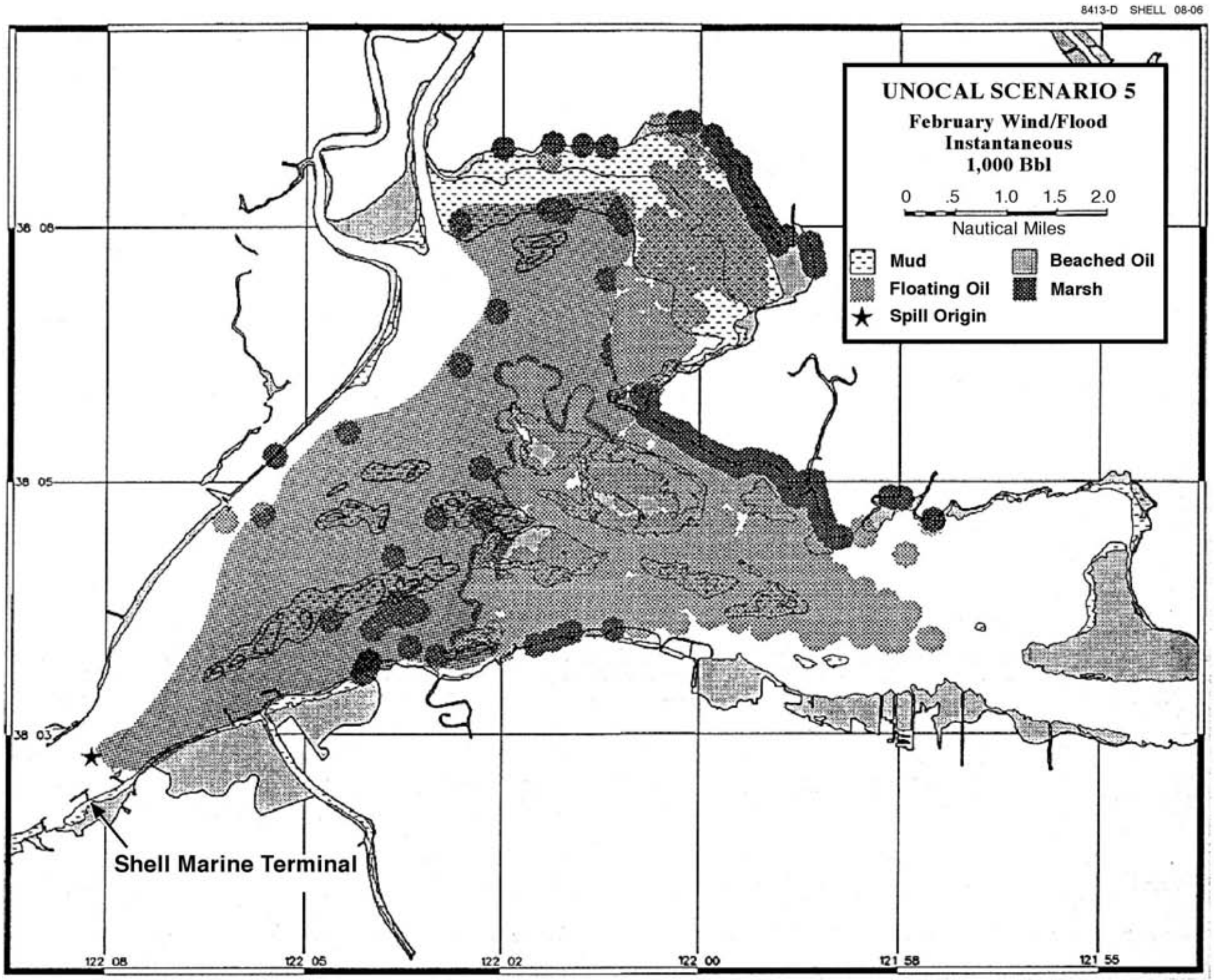


Chambers Group

Note:
Figure shows Lagrangian elements at 30-minute intervals for complete duration of spill.

BAY SCENARIO NO.4
20,000 BBL CRUDE SPILL FROM
TANKER ROUTE, JUNE WIND/FLOOD TIDE
Figure 4.2-5

Bay Scenario No. 4. Scenario No. 4 was a 20,000-bbl spill of crude oil released over a 24-hour period along the tanker route about 2 kilometers northwest of the ConocoPhillips (former Unocal) Marine Terminal. The modeled spill was moved by a sequence of winds beginning June 26, 1990, and a flood tide; all spill elements had beached after 63 hours. Initially, oil was carried on flood tide through the Carquinez Strait and deep into Suisun Bay, and then carried on ebb tide into central San Pablo Bay. Contact with the shoreline was continuous from Mare Island along the north side of Carquinez Strait to Army Point (at the northern terminus of the Benecia-Martinez Bridge), and along the south side from Davis Point to the town of Crockett. Patches of oil also beached from Martinez to Port Chicago and in Suisun Bay on Simmons Island (part of Grizzly Island).

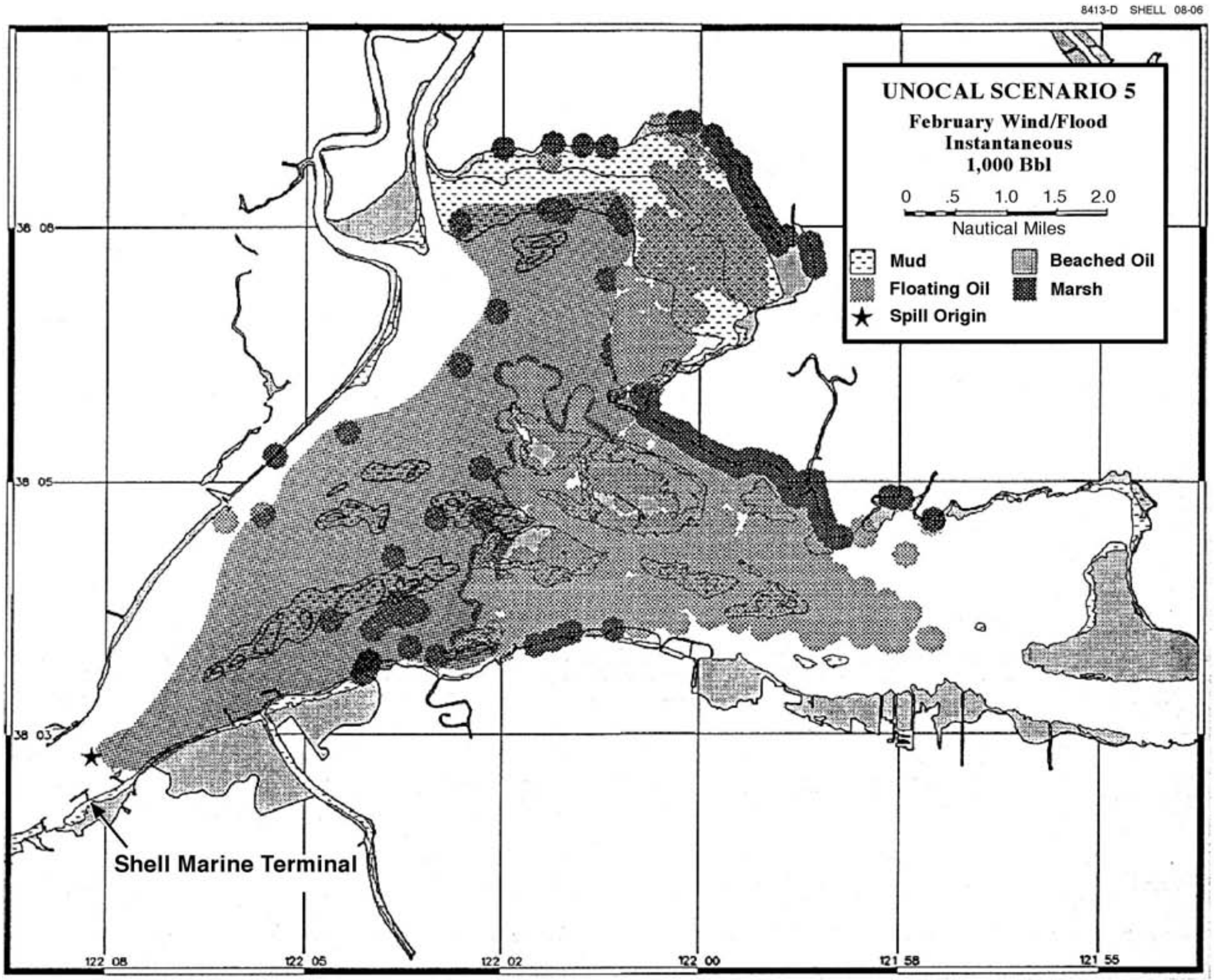


Chambers Group

Note:
Figure shows Lagrangian elements at 30-minute intervals for complete duration of spill.
Darker dots not along shoreline result from Lagrangian elements crossing.

BAY SCENARIO NO. 5
1,000 BBL CRUDE SPILL IN TANKER LINE-EAST END OF CARQUINEZ STRAIT, FEBRUARY WIND/FLOOD TIDE
Figure 4.2-6

Bay Scenario No. 5. Scenario No. 5 was a 1,000-bbl spill of crude oil released in the tanker land at the east end of Carquinez Strait. The modeled spill was moved by a sequence of winds beginning February 14, 1990, and a flood tide; all spill elements had beached after 27 hours. Within the first 3 hours, winds and currents carried oil out of the Strait and into Suisun Bay. Over the next 24 hours, oil spread extensively to contact intertidal mudflats in Grizzly Bay, and around Roe, Ryer and Simmons Islands in Suisun Bay. Shoreline contact occurred predominately along eastern Grizzly Bay and the south side of Simmons and Dutton Islands.



Chambers Group

Note:
Figure shows Lagrangian elements at 30-minute intervals for complete duration of spill.
Darker dots not along shoreline result from Lagrangian elements crossing.

BAY SCENARIO NO. 5
1,000 BBL CRUDE SPILL IN TANKER LINE-EAST END OF CARQUINEZ STRAIT, FEBRUARY WIND/FLOOD TIDE
Figure 4.2-6

Bay Scenario No. 6. Scenario No. 6 was a 1,000-bbl spill of crude oil released in the tanker land at the east end of Carquinez Strait. The modeled spill was moved by a sequence of winds beginning June 20, 1990, and a flood tide; all spill elements had beached after 12 hours. Most oil from this scenario beached within a few hours of release along the south shore of Suisun Bay from about Pacheco Creek to Middle Point, including the Avon-Port Chicago Marsh.

This page intentionally left blank.

Appendix B-2

SENSITIVE RESOURCES AND SPILL MODEL AND TRAJECTORY ANALYSIS FROM SHORE TERMINALS OIL SPILL RESPONSE PLAN
MARCH 2001
(Reproduced from Shore Terminals LLC DEIR, May 2004)

This page intentionally left blank.

2.6 SENSITIVE RESOURCES

San Francisco Bay is subjected to varying water sources, salinities, and currents related to the input from two major rivers and oceanwater input from the Golden Gate area. Much of the bay is industrialized; however, natural mudflats, saltflats, channelized stormwater runoff areas, and rocky shorelines also occur. Much of the "wetland" areas support sensitive biological resources and the shallow, protected nature of the bay provides spawning and nursery habitats for important commercial and sportfish species. Several ports are present throughout the bay; these ports are important economic centers for import and export of material used throughout the world.

Sensitive bird species utilize the open water and wetland habitats for overwintering, resting, and nesting activities and the bay is utilized by the winter run salmon as it migrates up the Sacramento River. In-bay fisheries include the herring roe shorebased operations. Several rare, threatened and/or endangered birds, mammals, and plants exist along the shorelines and/or utilize the water areas during various seasons.

2.6.1 Protection of Sensitive Sites

The sites and strategies were developed by the Area Committee and are from the Area Contingency Plan for the San Francisco Bay Area. Additional discussion of sensitive environmental sites is provided in the San Francisco Bay/ Delta Area Contingency Plan. This is the **guiding document** to use for establishing strategies and identification of sensitive sites at risk

Initial sensitve environmental protection response priorities for the first 24 hours have been identified by the terminal and listed in Table 2-11. These priorities are for guidance purposes only to aid with initial planning and identification of potential risk priorities. The listed priorities should be adjusted as identified by Planning Section and OSPR.

2.6.2 Wildlife Rehabilitation

In the event that wildlife is impacted or likely to become impacted, Shore Terminals will utilize the California Oiled Wildlife Care Network (OWCN) to provide wildlife rehabilitation. A copy of the letter committing Shore Terminals to participation in the OWCN is included at the end of this section.

Contact and mobilization information is identified in Section 2.1 Table 2-3.

2.6.3 Economical/ Recreational Sensitive Areas

Recreational and economically important areas in the San Pablo-Suisun Bay area that may require special protection in the event of an oil spill follow the guideance provided in the San Francisco Bay ACP sections 4600, 5400, and 9600.

TABLE 2-11 - INITIAL 24 HR. SENSITIVE AREA AT RISK SUMMARY

Winter Season - Range of Possible Impact During The Initial 24 Hrs

Adjust for Actual Current Flow and Wind Direction

Site ID	Impact BY HR (Ref.OCA)	Site Description	Assignment	Date/Time Required	Date/Time Completed
SF-695	N/A	Suisun Marsh North: Denverton / Nurse Slough Drainage			
SF-690	N/A	Suisun Marsh Central: Grizzly Isl			
SF-680	N/A	Suisun Marsh West; Suisun Slough			
SF-630C	3 hr.	Suisun Shoal			
SF-605	3 hr.	Hastings Sl., Point Edith and Seal Isl.			
SF-603	3 hr.	Bulls Head Marsh and Pacheco Creek			
SF-601	3 hr.	Martinez Marsh and Shell Dock Marsh			
SF-652	3 hr.	Benicia Marsh			
SF-654	6 hr.	Goodyear Marsh			
SF-651	6 hr.	Southampton Bay			
SF-632	6 hr.	Ryer Island			
SF-631	6 hr.	Roe Island			
SF-670	12 hr.	Honker Bay			
SF-668	12 hr.	Dutton Island			
SF-667	12 hr.	Freeman & Snag Islands			
SF-665	12 hr.	Simmons Island			
SF-633	12 hr.	Middle Ground Island			
SF-607	12 hr.	Belloma Slough			
SF-672	12 hr.	Honker Bay North – Spoonbill Ck and Vansickle Island			
SF-671	12 hr.	Honker Bay West – Wheeler Island			
SF-660	12 hr.	Grizzly Bay			
SF-655	18 hr.	Joice Island, Suisun Slough, and Montezuma Slough			
SF-583	18 hr.	Napa River Marshes			
SF-673	24 hr.	Honker Bay East – Chipps Island Shore			
SF-608	Over 24 hr	Shore Acres Marsh			

Note: 1) The time for impact is based on proximity determined by the OCA Trajectory scenario for the initial 24 hr. period. Apply specific trajectory for specific environmental conditions and protection priorities.
2) Refer to Section 3 for details on the OCA Trajectory.
3) N/A indicates that there was no forecasted impact from the OCA Trajectory scenario;

In event of an actual response, protection priorities should consider actual wind and state of tidal current conditions and adjust the OCA priorities accordingly.

TABLE 2-11 - INITIAL 24 HR. SENSITIVE AREA AT RISK SUMMARY

Summer Season - Range of Possible Impact During The Initial 24 Hrs

Adjust for Actual Current Flow and Wind Direction

Site ID	Impact BY HR (Ref.OCA)	Site Description	Assignment	Date/Time Required	Date/Time Completed
SF-695	N/A	Suisun Marsh North: Denverton / Nurse Slough Drainage			
SF-690	N/A	Suisun Marsh Central: Grizzly Isl			
SF-680	N/A	Suisun Marsh West; Suisun Slough			
SF-630C	3 hr.	Suisun Shoal			
SF-605	3 hr.	Hastings Sl., Point Edith and Seal Isl.			
SF-603	3 hr.	Bulls Head Marsh and Pacheco Creek			
SF-654	6 hr.	Goodyear Marsh			
SF-652	6 hr.	Benicia Marsh			
SF-632	6 hr.	Ryer Island			
SF-631	6 hr.	Roe Island			
SF-601	6 hr.	Martinez Marsh and Shell Dock Marsh			
SF-668	12 hr.	Dutton Island			
SF-667	12 hr.	Freeman & Snag Islands			
SF-665	12 hr.	Simmons Island			
SF-655	12 hr.	Joice Island, Suisun Slough, and Montezuma Slough			
SF-651	12 hr.	Southampton Bay			
SF-633	12 hr.	Middle Ground Island			
SF-607	6 hr.	Belloma Slough			
SF-672	12 hr.	Honker Bay North – Spoonbill Ck and Vansickle Island			
SF-671	12 hr.	Honker Bay West – Wheeler Island			
SF-670	18 hr.	Honker Bay			
SF-660	18 hr.	Grizzly Bay			
SF-673	18 hr.	Honker Bay East – Chipps Island Shore			
SF-608	18 hr	Shore Acres Marsh			
SF-702	18 hr.	Stake Point Marsh			
SF-752	24 hr.	Chipps Isl. South			
SF-755	24 hr.	Spoonbill Creek			
SF-705	24 hr.	Mallard Island			
SF-583	Over 24 hr.	Napa River Marshes (Mare Isl. St.)			

Note: 1) The time for impact is based on proximity determined by the OCA Trajectory scenario for the initial 24 hr. period. Apply specific trajectory for specific environmental conditions and protection priorities.
2) Refer to Section 3 for details on the OCA Trajectory.
3) N/A indicates that there was no forecasted impact from the OCA Trajectory scenario;

In event of an actual response, protection priorities should consider actual wind and state of tidal current conditions and adjust the OCA priorities accordingly.

3.4 OFFSITE CONSEQUENCES ANALYSIS

3.4.1 Introduction

This Offsite Consequence Analysis (OCA) is intended to supplement the Hazard Analysis for identifying the impact area from the Reasonable Worst Case Discharge (RWCD) at the facility. The Hazard analysis, which is documented separately, focused on the identification of possible hazards that may result in an oil spill from the facility. Whereas, the goal of the OCA is to identify from a given spill scenario the credible impact area and the potentially impacted sensitive environmental sites over a 72 hour period.

The Offsite Consequence Analysis involved a progressive study of the spill site involving evaluation of the sensitivity of spill trajectories to pessimistic seasonal weather and environmental conditions, 72 hour spill trajectory for the identified pessimistic conditions, and identification of the area at risk from a spill and the potential impacted sensitive sites. This analysis was performed and documented by BlueWater Consultants, Novato, California using the "OILMAP" spill modeling software by ASA.

The results of the trajectory analyses are shown on color maps delineating time contours for the extent and impact of oil discharged from the terminal location. The trajectory plots display the differences with seasonal conditions and types of products.

The impact areas have been correlated to the sites identified by the ACP (12/97 ed.) The planned protection and recovery strategies would follow the recommendations contained in the ACP. This information includes a description of the area, shoreline characteristics, identification of sensitive marine resources, and strategy for deployment of resources.

3.4.2 Spill Model And Trajectory Analysis Approach

Analysis Approach

The offsite consequence analysis involved a progressive study for each site involving the following tasks:

a. Sensitivity analysis of spill trajectories to seasonal weather and environmental conditions

b. 72 hour spill trajectory for the identified pessimistic conditions

c. Identification of the area at risk from a spill and the potential impacted sensitive sites.

The area at risk from a release at site was evaluated using a trajectory and fates modeling analysis for potential RWCD spill volumes, which may result from oil transfer operations. A sensitivity analysis was performed on these results to evaluate possible seasonal environmental and weather impacts. This was performed using stochastic evaluation technique for trajectories over each seasonal period. The identified pessimistic conditions were used to develop trajectory plots depicting the projected areas of impact over a 72-hour period. These trajectories are based on specific type of products and have incorporated weathering and fates considerations for the oil.

The areas at risk of impact from the analysis have been compared to the sites identified in the latest edition of the Area Contingency Plan. California State representatives, USCG representatives, local city and county representatives, environmental groups, and industry representatives develop the ACP through a joint effort.

The sites considered through the ACP process include:

- water intakes
- lakes and streams
- fish and wildlife
- recreational areas
- endangered flora and fauna
- wetlands or other environmentally sensitive areas
- other areas of economic importance including sensitive terrestrial environments, aquatic environments, and unique habitats

Oil Spill Model

The analyses were completed using oil spill modeling software OILMAP for Windows V2.4 from Applied Science Associates (ASA). Several modeling modes within OILMAP were applied to the analysis. These modes were configured to address specific types of spill impact including assessment of different response scenarios on the spill fate, spill trajectory and weathering prediction, and statistical probabilities of shoreline impact of the spilled oil.

The oil spill trajectory analysis for support of the Offsite Consequence Analysis involved primarily the Trajectory, Fates, and Stochastic modes which are summarized below:

Trajectory and Fates Mode

The trajectory and fates mode of operation predicts both the movement and weathering of surface oil. The fate processes simulated are spreading, evaporation, entrainment, emulsification and shoreline stranding.

Either instantaneous or continuous spills with a constant oil release rate can be simulated. Each spillet is transported and weathered independently. The oil composition, selected by the user from a library of oil types, is characterized by its boiling point curve. This characterization allows the model to accurately predict the weathering of a wide variety of crude and refined oil products.

Stochastic Mode

In the stochastic mode, a user-specified number of spill simulations are executed varying only the environmental conditions at the time of the spill. The stochastic model includes all the weathering processes in the trajectory and fate model.

The spill release occurs at random times over a period of time (by month to over an entire year). Historical wind records from regional meteorological stations can be used, or the model can generate wind time series from zero- or first-order statistical wind distributions.

The multiple trajectories predicted by the stochastic model are summarized as probability contours showing the probability of land and water areas being impacted by oil spilled at the specified release site. The probability contours form an envelope showing the direction(s) oil will move from the site and where it will impact land. Simulation results enable the user to assess potential extent of the area at risk for that seasonal period.

3.4.3 Application Of Oilmap Model To Spill Scenarios

Oil Spill Scenario

The Reasonable Worst Case Discharge (RWCD) scenario identified by the Oil Spill Contingency Plan was used to evaluate the potential impact on the shoreline. The sensitivity Analysis evaluated the potential risk from the RWCD spill at the Martinez Facility. These parameters for the spill risks are summarized in the following table:

Table 3-3 - Oil Spill Modeling Scenario Information

Facility	Shore Terminals – Martinez
Product:	Group 3 oil (Crude Oil)
Quantity	5,830 bbls
Source Location:	Rupture of line at dock Considering: Line pumping rate (20,000 bph) Time for discovery, and S/D (30 min.)
Seasonal Considerations:	Scenario during both summer and winter conditions

In each scenario, the spill was considered to be instantaneous discharge at the identified location. The model calculation time step was 10 minutes, with a dispersion factor of 1.5 m^2 / sec. This was considered to provide model simulation for the surface conditions and environmental constraints for the area. The simulations were run until the oil was fully dissipated from either evaporation, dissolution, or grounded on-shore over a period of 72 hours (3 days.)

In each scenario, the spill was considered to be instantaneous discharge at the identified location. The model calculation time step was 10 minutes, with a dispersion factor of 1.5 m^2 / sec. This was considered to provide model simulation for the surface conditions and environmental constraints for the area. The simulations were run until the oil was fully dissipated from either evaporation, dissolution, or grounded on-shore over a period of 72 hours (3 days.)

3.4.4 Environmental Data

<u>**Hydrodynamic**</u>

Tidal current and river induced flows, providing input to OILMAP for San Pablo Bay, were derived from a three- dimensional, depth contoured, finite element hydrodynamic model of San Francisco Bay (ASA et al., 1998). The model generates equations for water motion predicted from the charted depth gradients and forcing conditions.

For development of the hydrodynamic model, the bay was represented by a finite element mesh consisting of three-dimensional (e.g., rectangular, triangular) and two-dimensional elements. The grid covers the entire bay from the entrance at Golden Gate Bridge and both the south and northern branches of the bay.

The model was forced by tidal elevation at the open boundary at the Golden Gate Bridge and river and freshwater flows from the Sacramento and San Joaquin Rivers. The resulting hydrodynamic output incorporates a net outflow longterm condition.

Wind

Wind data used in the model simulation was based on a regional statistical wind summary. Wind speed and direction time series for the Summer (July - August) and Winter (December - February) were created from summary data taken from the International Station Meteorological Climate Summary (NCDC, 1992) for the nearest recording site. Conditions were modified from the historical data from the Port Chicago meteorological station, located along the south shore of Suisun Bay, over the period of January 1995 to December 1996.

This wind data was compiled into monthly speed and direction probability tables. The tables are monthly statistical summaries of the probability of wind coming from a particular direction and within a range of speeds. The monthly data records generated are essentially a synthetic time series based on wind probabilities for the selected period.

3.4.5 Trajectory Results

Figure	Description
3-1.	Spill Time Contour Map - Summer Conditions
3-2.	Spill Time Contour Map - Winter Conditions
3-3.	Probability of Water Surface Oiling Map- Summer Conditions
3-4.	Probability of Water Surface Oiling Map- Winter Conditions

The modeling period was a maximum of 72 hours. The time required the oil to reach the shoreline is determined by the tide stage and the speed, direction of the wind, and the amount of material loss to evaporation.

The Spill Trajectory maps display the extent of oiling over a 72-hour period. A scale is provided on the map for the time period color key. A legend to the time contour color scale is provided on each map. Shoreline impacts are identified by red markings. As a conservative factor, the shoreline characteristics have been negated to allow maximum refloating and circulation of the oil particles.

The model has incorporated weathering effects on the oil and partial loss by evaporation, and mixing with the water column. The Predicted Weathering and Fates Graph – Figure 3-5 in this section represents the relative mass balance over the 72-hour period.

Sensitivity Analysis Results

Seasonal variations have been evaluated through the stochastic model. Historical winds for the period were categorized into summer and winter seasons. Wind velocity and direction vectors representative for the seasons were evaluated creating a range of probable spill trajectories.

Generally, the regional weather has two seasonal conditions, summer and winter. In the summer, winds are dominated by the prevailing west wind and thermal induction from the valley. In the early morning and evening, winds can be light and variable. In the winter or fall, the winds are generally light and variable, with occasional stronger winds representative of passing winter storm systems. Generally, a strong wind across the tidal flow tends to act as a driving function forcing the spill out of the main tidal flow. This can result in earlier grounding on the shoreline and may result in less travel and shoreline area impact.

The Spill Contour maps represent a summary of 100 iterations of spill trajectories from various states of tidal currents and seasonal environmental factors. These results are depicted on color maps delineating contours of oiling probability. A legend to the color scale is provided on each map. Shoreline impacts are identified by red markings or by the overrun of the contour across the shoreline

For the Martinez Facility RWCD Spill Risk, the greatest shoreline impact was determined to be during the winter with the increased impact along the shoreline of Carquinez Straits and along the southeastern shoreline of San Pablo Bay. Impact during the summer is earlier and to the northern reaches of Suisun and Grizzly Bays.

Spill Trajectory Results

The RWCD scenario was modeled in the trajectory and fates mode using the selected pessimistic seasonal data. The modeling time period was up to 72 hours (three days.)

The model incorporates weathering effects on the oil, loss by evaporation, and mixing with the water column. Shoreline characteristics are included in the model and provide consideration for credible shoreline grounding.

The trajectory output information has been extracted from this output to provide a sequential listing of the impacted sites. Table 2-11 in Section 2.6 of this plan lists these sites with their relative time frames and order of impact during the intitial 24 hrs.

A summary of the relative rate of loss to the environment from the spill is provided in the Figure 3.2-5 - Weathering & Fates Graph.

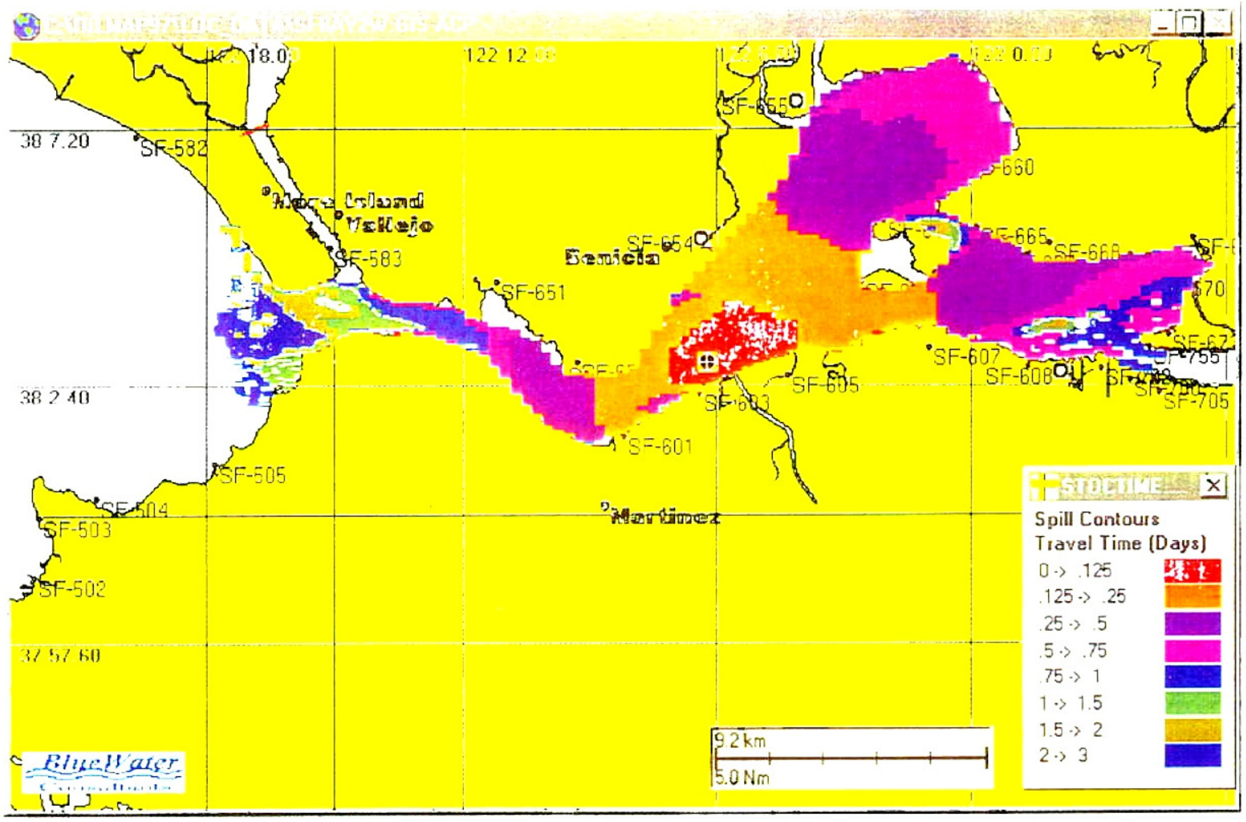


FIGURE 3.4-1 - SPILL TIME CONTOUR MAP - SUMMER CONDITIONS

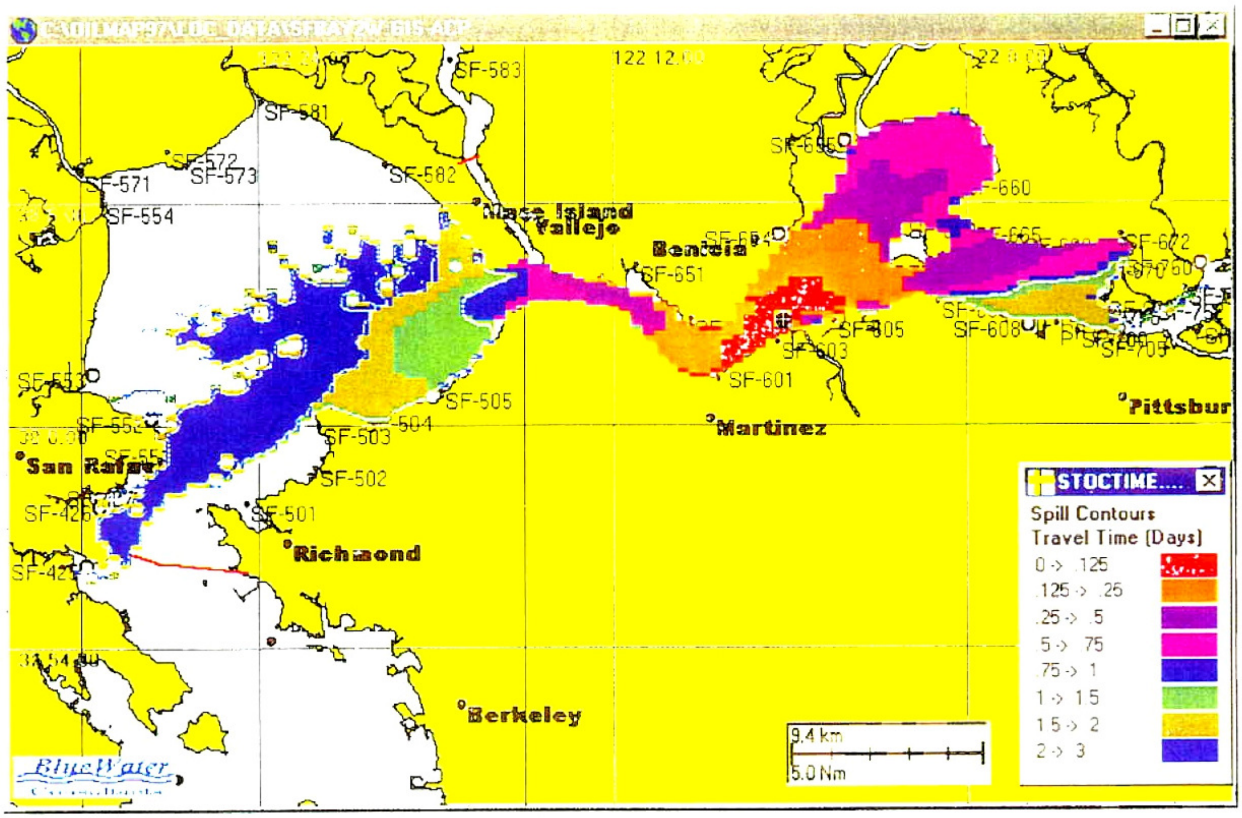


FIGURE 3.4-2 - SPILL TIME CONTOUR MAP - WINTER CONDITIONS

Shore Mart-3v2 Rev. 8/00

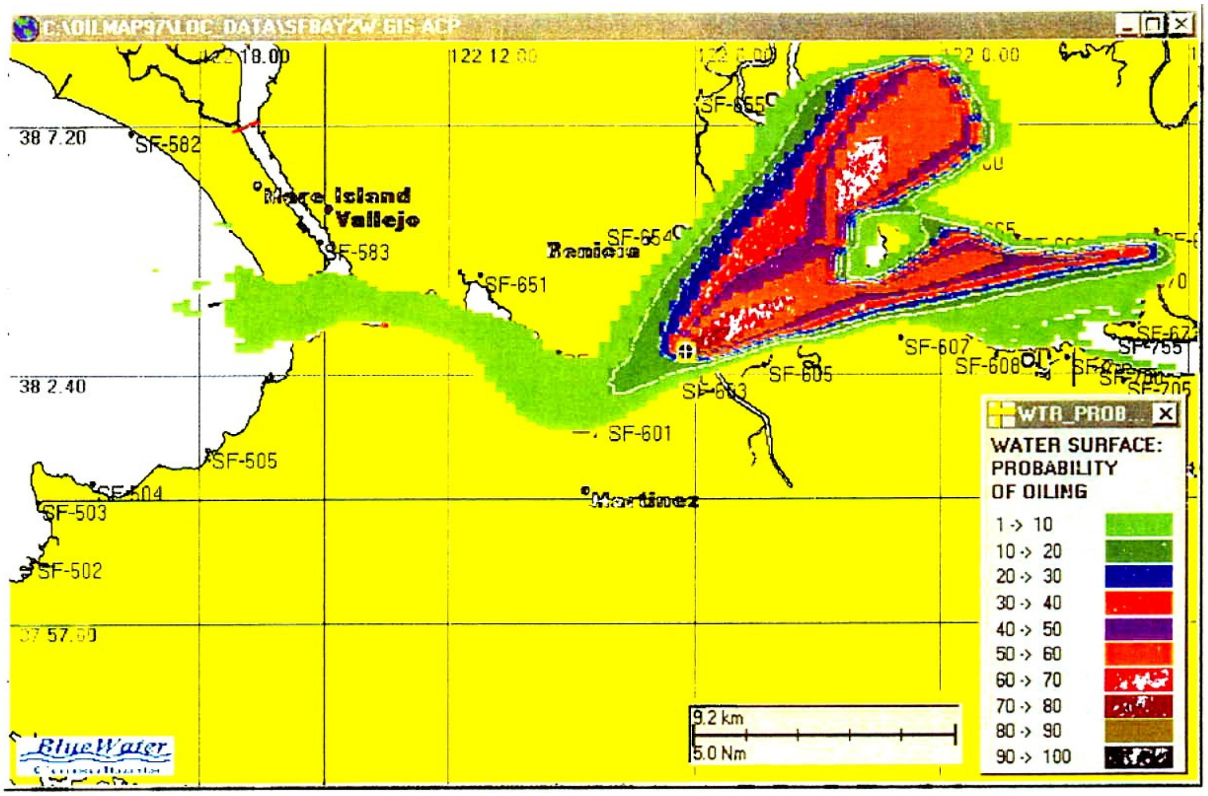


FIGURE 3.4-4 – PROBABILITY OF SURFACE OILING - WINTER CONDITIONS

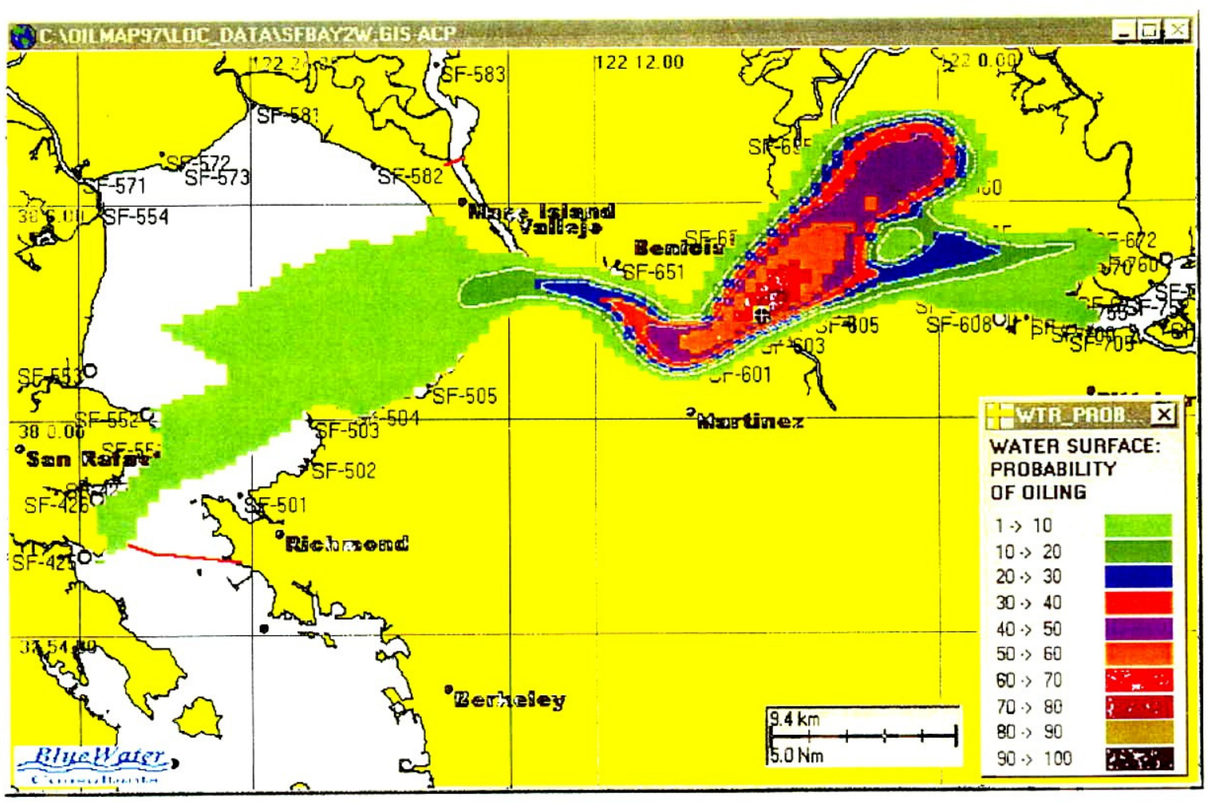


FIGURE 3.4-3 – PROBABILITY OF SURFACE OILING - SUMMER CONDITIONS

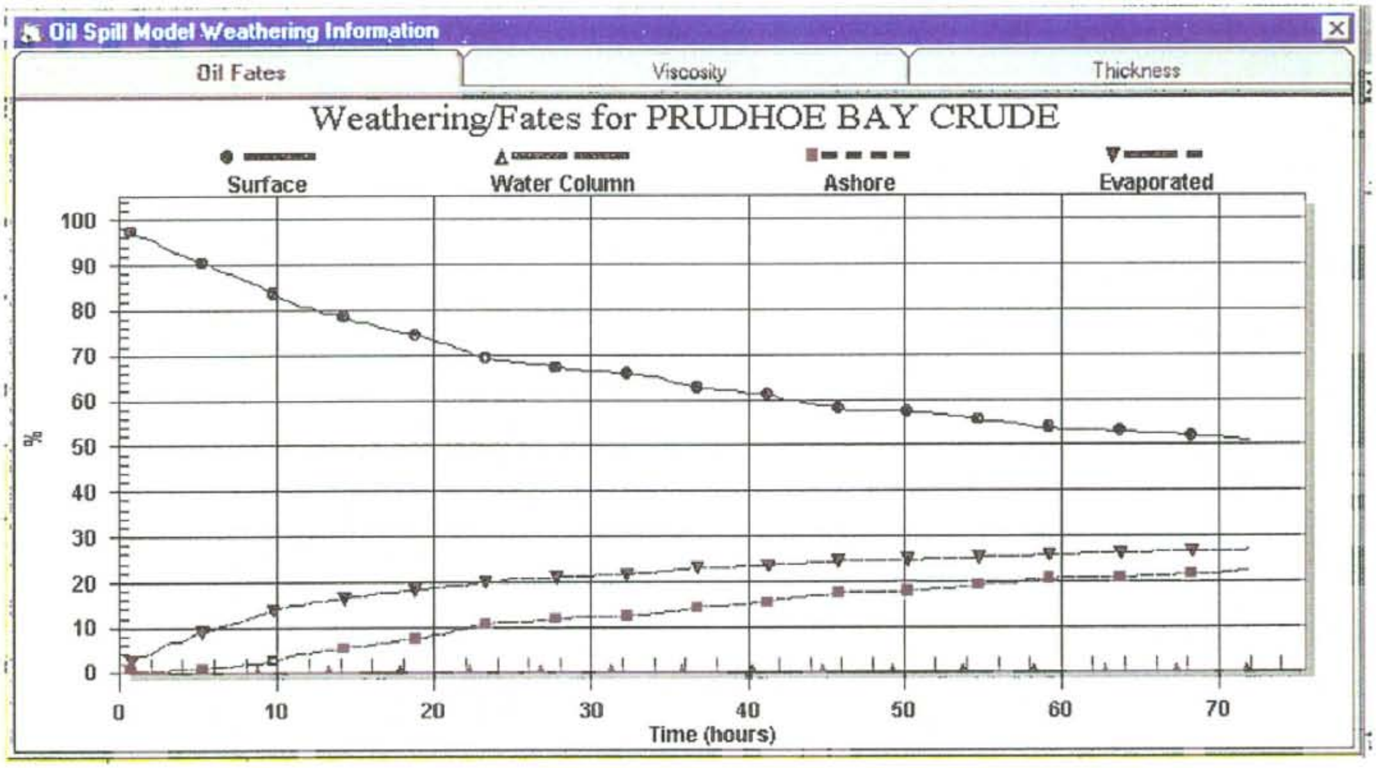


FIGURE 3.4-5 WEATHERING AND FATES GRAPH

Shore Mart-3v2 Rev. 8/00

Appendix B-3

CLEAN BAY TRAJECTORY ANALYSIS CONTAINED IN WICKLAND OIL MARTINEZ APPLICATION RESPONSES AND SUPPORTING APPENDICES, SEPTEMBER 17, 1998 (Reproduced from Shore Terminals LLC DEIR, May 2004)

This page intentionally left blank.

202 Trajectory Analysis

202.1 Introduction

The OSPR regulations require that tankers and barges conduct trajectory analyses for the significant hazards identified in the Navigational Hazards Analysis (Section 201). All marine facilities are also required to conduct a trajectory analysis. The results of these trajectory analyses are used to determine the environmental consequences of an oil spill. The regulations state that trajectories be predicted as the basis for determining those areas and shoreline types for which resource strategies must be developed. According to the regulations, a trajectory analysis shall

- apply to the reasonable worst-case oil spill volume;
- determine the potential direction, rate of flow, and time of travel of the reasonable worst-case oil spill;
- determine the outer perimeter of a spill;
- be based on regional extremes of climate, tides, currents, and wind;
- consider seasonal differences; and
- assume pessimistic water and air dispersion and other adverse environmental conditions.

This section describes the trajectory analysis performed for Clean Bay. Spill envelopes were developed that defined the potential limit of a spill under regional extremes of a variety of meteorological and oceanographic conditions. For purposes of this document, a spill envelope encompasses a segment of coastline over which spilled oil may impact the coast over time based on these extreme environmental conditions, and the chemical and mechanical properties of the substance spilled.

It should be noted that the spill envelopes presented here do not represent the trajectory of any one oil spill. In fact, no single spill could possibly impact the coastline over the entire spill envelope, since the envelopes were calculated by considering the entire range of possible spill trajectories. A single spill could not simultaneously move along all of the trajectories used to develop the spill envelope.

As discussed in the following methods section, the oil spill volumes considered varied over several orders of magnitude. Facility spills were generally smaller than spills from vessel hazard areas. In fact, many of the facility spill volumes were much less than the available daily cleanup capacity for the facility. For these facilities, it is likely, however, that spill response and cleanup would occur within 1 day. Nonetheless, for the purposes of calculating a spill envelope, it was conservatively assumed that the facility spills would not be contained until 3 days after the initial release. It was assumed that vessel spills, which are generally larger and farther removed from cleanup equipment, would require more than local resources for response and cleanup. For these spills, a 3-day period before containment was also assumed.

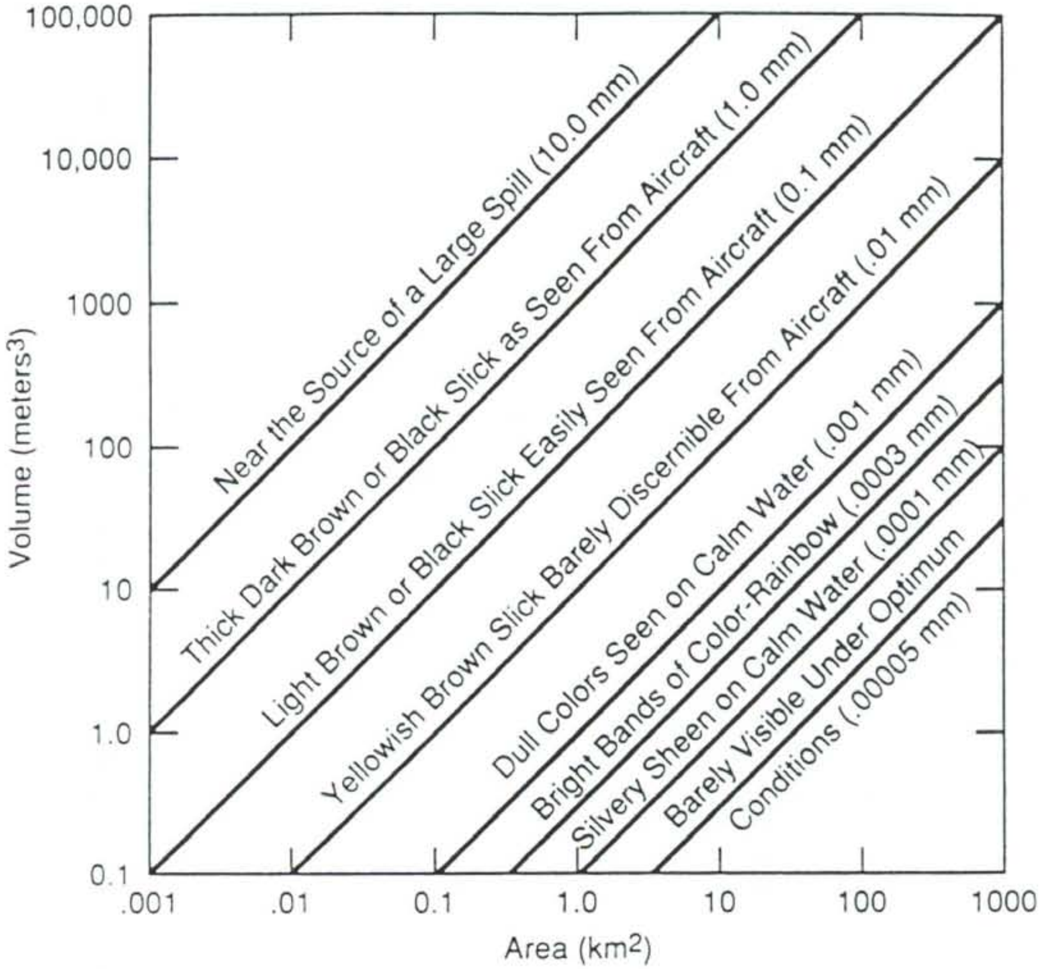
202.2 Methods

Transport of spilled oil was based on two factors: 1) environmental effects and 2) properties of crude oil. The environmental transport mechanisms included wind stress, tidal advection and dispersion, large-scale oceanic currents, and riverine effects. Not all these transport mechanisms applied to each spill site. Other effects that contributed to transport from the spill site or spill volume reduction included evaporation and spreading due to gravity and surface tension.

To simplify the analysis, a generic California crude oil was selected as a target spill hazard because it is the most persistent petroleum substance that is likely to be spilled. As previously mentioned, spill envelopes were developed for all facility and vessel hazards for 3 days.

Calculation of the spreading of a spill was based on the work of Fay (1971). The calculations for spreading included the effects of gravity, inertia, viscous forces, surface tension, evaporation, and dispersion. For simplicity, it was assumed that the spill always spread radially. The model does not account for recovery, stranding, dispersion in high energy waves, or other removal. Nor does the envelope generated represent the amount of oil stranded or contaminating any area within the envelope.

Some second-order mechanisms that affect oil transport and persistence in the marine environment were considered. The spreading calculations considered how loss and degradation processes limit the physical spreading of the spill. The thickness of the oil was factored into the analysis as a function of initial spill volumes. Generally, the slick was no longer considered once it was not visible from the air. For most analyses, the final oil thickness was approximately 0.1 millimeter (mm) and never less than 0.01 mm (Figure 202-1).



Conversion Factors

Area

1 ft^2 = 9.3 x 10^{-8} km^2
1 yd^2 = 8.4 x 10^{-7} km^2
1 mi^2 = 2.6 km^2

Volume

1 bbl = 0.16 m^3
1 U.S. gal = 3.8 x 10^{-3} m^3

Source: Exxon 1992, Oil Spill Response Field Manual

FIGURE 202-1. Areal Coverage of Spilled Oil for Different Thicknesses

Beaching of oil was also considered initially, through the use of a Monte-Carlo simulation of oil dispersion near a shore. The dispersion of the spill was modeled by considering the spill to be a collection of "packets," each performing a random-walk, with the step size related to the horizontal dispersion coefficient. This technique is frequently used in numerical models of oil spill transport (e.g., Shen and Yapa 1988). A dispersion coefficient of 5 square meters per second was taken from the literature (Shen and Yapa 1988). The spill was assumed to also spread laterally by the physical spreading processes mentioned above. Any packet of oil striking the beach was not transported further. This analysis predicted that approximately 70 percent of a small spill (300 bbl) would beach within 3 days. A smaller percentage of the large spills would beach over this time period (Figure 202-2). Based on this analysis, it was decided that beaching of oil would remove much, but not all of a spill over a 3-day time period.

The method for developing spill envelopes was based on a simple lagrangian analysis of oil spill transport. This method is based on a vector addition to transport forces at work at the site of the spill. These transport mechanisms were applied sequentially depending on the likelihood of being present during the time of spill. For example, mechanical spreading and transport due to tidal currents were applied prior to transport by wind stress because wind stress may be ephemeral whereas spreading and tidal currents are omnipresent.

The tidal currents for San Francisco Bay were based on the published National Oceanic and Atmospheric Administration (NOAA) current charts (DOC 1973). Tidal currents outside the mouth of the Golden Gate were based on commercially available software (Micronautics 1993). Wind speed and direction data for numerous locations within San Francisco Bay, outside the bay, and in Monterey Bay were derived from California Surface Wind Climatology (1992). Estimates of river flow for the San Joaquin and Sacramento Rivers were obtained from U.S.G.S. gauging station data as compiled by the Hydrodata software.

Facility and vessel hazards sites were classified into five zones based on location and transport mechanisms. The zones are listed below:

- Northern San Francisco Bay
- Central San Francisco Bay
- Southern San Francisco Bay
- Outside San Francisco Bay
- Monterey Bay

Tables 202-1 and 202-2 list the facility and vessel navigation hazards for Clean Bay. Individual trajectory analyses are presented in Section 202.4.

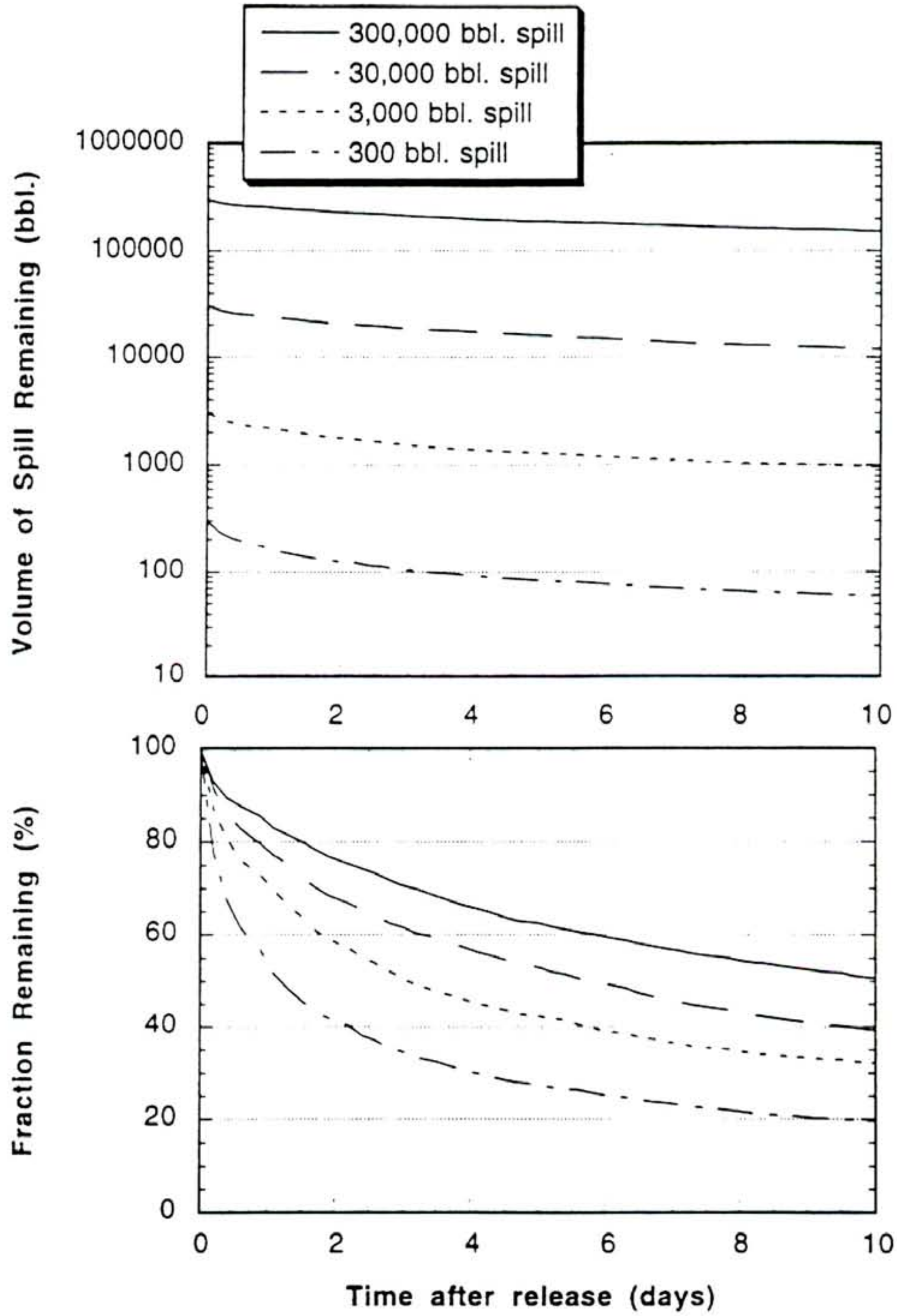


FIGURE 202-2. Effect of Beaching on Volume of Spill Remaining and Fraction of Spill Remaining

TABLE 202-1

Trajectory Analysis Location and Volumes
Facility Worst Cases

	Origin of Trajectory	Affected Facilities	Volume Analyzed (bbl)
1	Benecia/Martinez Bridge	Exxon Refinery Huntway Santa Fe Pacific Pipelines Tosco (Avon) Martinez Terminal (Wickland) Tosco (Amorco) Shell Oil Wharf	4,000 * 10,000 *
2	Union Oil Docks	Unocal Refinery Wickland Oil (Crocket) Pacific Refinery (Rodeo)	10,000 * 20,000 *
3	Chevron Refinery Long Wharf	Chevron Refinery Long Wharf	30,000
4	Mouth of Harbor Channel (Richmond)	Unocal Arco Time Oil GATX (Vegetable Oil) Castrol Texaco	3,826 * 800 *
5	Moss Landing Harbor	PG&E Power Plant	9,000
6	Pittsburg	PG&E	10,000
7	Redwood City	Gibson Oil	2,000
8	San Francisco - Pier 70	PG&E	50,000

* Trajectory analyses were conducted for both volumes.

TABLE 202-2

Trajectory Analysis Location and Volumes
Vessel Worst Cases

Hazard Location	Maximum Vessel Capacity (bbl)	OSPR Worst-Case Spill Size (bbl)
INSIDE SAN FRANCISCO BAY		
1 Harding Rock	1,200,000	300,000
2 Anchorage #9	1,200,000	300,000
3 Richmond/San Rafael Bridge	575,000	143,750
4 Carquinez Bridge	575,000	143,750
5 Benecia/Martinez Bridge	575,000	143,750
OUTSIDE SAN FRANCISCO BAY		
1 Precautionary Area to San Francisco Bay	1,200,000	300,000
2 Moss Landing	350,000	87,500

202.2.1 Consideration of Previous Spill Trajectories

The spill envelopes described in this document were developed by combining a series of trajectory analyses each of which use separate sets of conservative assumptions to predict all areas that could possibly be affected from a spill from a single location. To ensure that no potential receptor was omitted, the analyses included the assumptions that oil would be driven under regional extremes of climate, tide, current, and wind.

For comparison of the modeling assumptions, a study for an earlier contingency planning effort for Clean Bay (Clean Bay 1991) was reviewed. In the earlier study, spill envelopes were calculated for releases at three locations within San Francisco Bay (Anchorages 8 and 9, Richmond Long Wharf, Rodeo). Envelopes were calculated in the same basic way as in this study, i.e., by superposing the oil transport associated with spreading, tidal advection, and wind drift. The previous analysis used a much shorter time frame, however, as envelopes were calculated for a 3-hour, rather than 3-day, time period. Because the time scales and therefore the study assumptions differed, direct comparison of the envelopes is not possible. Nonetheless, a qualitative comparison, which is appropriate, was made of the two trajectory analyses. The two studies were found to be in qualitative agreement.

In order to evaluate the more likely movement of a spill, the results of another spill trajectory modeling effort were also reviewed and compared to the comparable spill envelope developed for this RRM project. The example chosen for comparison is included in a study prepared by the National Oceanic and Atmospheric Administration (NOAA) in which a "worst case" spill of crude oil at Harding Rock was modeled (San Francisco Bay/Delta ACP, 1993). Several assumptions were made as part of the NOAA study which were different from the assumptions required to develop the spill envelopes for the RRM site. Some of the major different assumptions included:

- NOAA used a smaller spill size (12,000 bbl vs. 300,00 bbl for the RRM)
- NOAA considered typical wind patterns compared to extreme winds
- NOAA used common tidal conditions rather than extreme tidal conditions

Based on these assumptions, the NOAA results are more representative of a single spill under typical conditions for this area. The NOAA results for the spill occurring at Harding Rock indicate that only a relatively small area would be affected compared to the results based on the assumptions required for the RRM.

As the purpose of the analysis included in this RRM is "to be used as the basis for determining the areas and shoreline types for which Response Strategies must be developed" [OSPR 817.02 (c)(2)], the envelopes included in Section 202 were developed specifically to fulfill this requirement. Again, the envelopes were developed to identify the outer perimeter of shoreline areas that could receive oil in the event of spills from an identified site.

202.2.2 Selection of Reasonable Worst-Case Scenarios

Table 202-3 indicates how the reasonable worst-case scenarios were selected for each of the five zones studied.

202.3 Spill Trajectory Prediction

Several tools are readily available for the real-time prediction of oil spill trajectories, including satellite photos, existing meteorological facilities, and tracker buoys. Satellite photos are available in near-real time from federal agencies, research institutions, and universities (e.g., NOAA and Jet Propulsion Laboratory [JPL]), which show, for example, sea surface temperature and sea surface roughness. These photos can provide synoptic overview of current patterns and wave conditions. These data can be used to assist prediction of oil spill transport and weathering. A network of existing on-shore meteorological facilities and offshore data buoys can provide real-time wind speed and direction information for transport prediction.

The National Weather Service (NWS), which is a line office within the NOAA, is responsible for providing up to date weather information in response to oil spills. NWS can provide such information as wind direction and speed, air and sea temperature, and direction and height of sea and swell. The NWS can also provide daily weather forecasts, as well as longer range forecasts (2 to 5 days).

Additionally, if the oil spill is in, or near to, a riverine system, the NWS's River Forecast Office can provide river flow rates and predicted flow rates as well.

In a spill response, river and weather information can be provided to the incident Commander or FOSC by the NWS via the NOAA Scientific Support Coordinator (SSC). An agreement between NOAA's Hazardous Materials Response and Assessment Division and NWS establishes the SSC as the point of contact in order to streamline the flow of information and to provide specialized weather needs without affecting the normal operating procedures of

TABLE 202-3

Methods for Selection of Reasonable Worst-Case Scenarios

	Zone	Primary Driving Forces		Worst-Case Scenario	Sites
1	Outside San Francisco Bay	Wind stress and the California Current/Davidson Current Influences	1	Davidson Current Influence with southerly winds resulting in a northward flow, and	Precautionary Area west of the entrance to San Francisco Bay Point Reyes (if it gets included)
			2	California Current Influence with northerly winds resulting in a southward flow.	
			3	Minimum oceanic current influence with easterly wind stress resulting in a westerly flow	
2	Monterey Bay	Wind stress and the California Current/Davidson Current Influences	1	Davidson Current Influence with southerly winds resulting in a northward flow, and	Moss Landing PG&E
			2	California Current Influence with northerly winds resulting in a southward flow.	
3	North San Francisco Bay	Wind stress and tidal currents	1	Westerly or southerly wind stress on a flood tide	All sites north and east of the Richmond/San Rafael Bridge
			2	Easterly or northerly wind stress on an ebb tide	
4	South San Francisco Bay	Wind stress and tidal currents	1	Northerly wind stress on a flood tide	All sites south of the Bay Bridge
			2	Southerly or easterly wind stress on an ebb tide	
5	Central San Francisco Bay	Wind stress and tidal currents	1	Easterly wind on an ebb tide	The sites bounded by the Bay Bridge, the Richmond/San Rafael Bridge, and the Golden Gate Bridge

the forecast office. Furthermore, the agreement provides for a dedicated meteorologist to assist NOAA in obtaining the most accurate and current information for operational planning and trajectory analysis.

The NOAA Scientific Support Coordinator can be contacted at:

NOAA/HMRAD
Suite 5110
501 West Ocean Blvd.
Long Beach, California 90802
(310) 980-4107
(800) SKY-PAGE (Pager - PIN# 579-8818)

Another readily available tool is the tracker buoy. A tracker buoy consists of a surface float rigged with a light, radar reflector, radio transmitter, or satellite tracking system. Tracker buoys can be deployed by boat or airplane at the periphery of an existing oil spill and used to monitor in real time the trajectory of an oil spill. Clean Bay has tracker buoys and tracker equipment available.

The California Oil Spill Cooperatives have also contracted for the use of a radiometric oil spill surveillance system (ROSSS) to provide almost real-time tracking of oil. A more detailed discussion of ROSSS is included in Section 500.

202.4 Trajectory Analyses

Spill trajectory envelopes have been calculated for the facilities and vessel navigation hazards within the Clean Bay area of interest. Analyses and corresponding maps are presented in this section.

This Page Intentionally Left Blank

Trajectory Maps

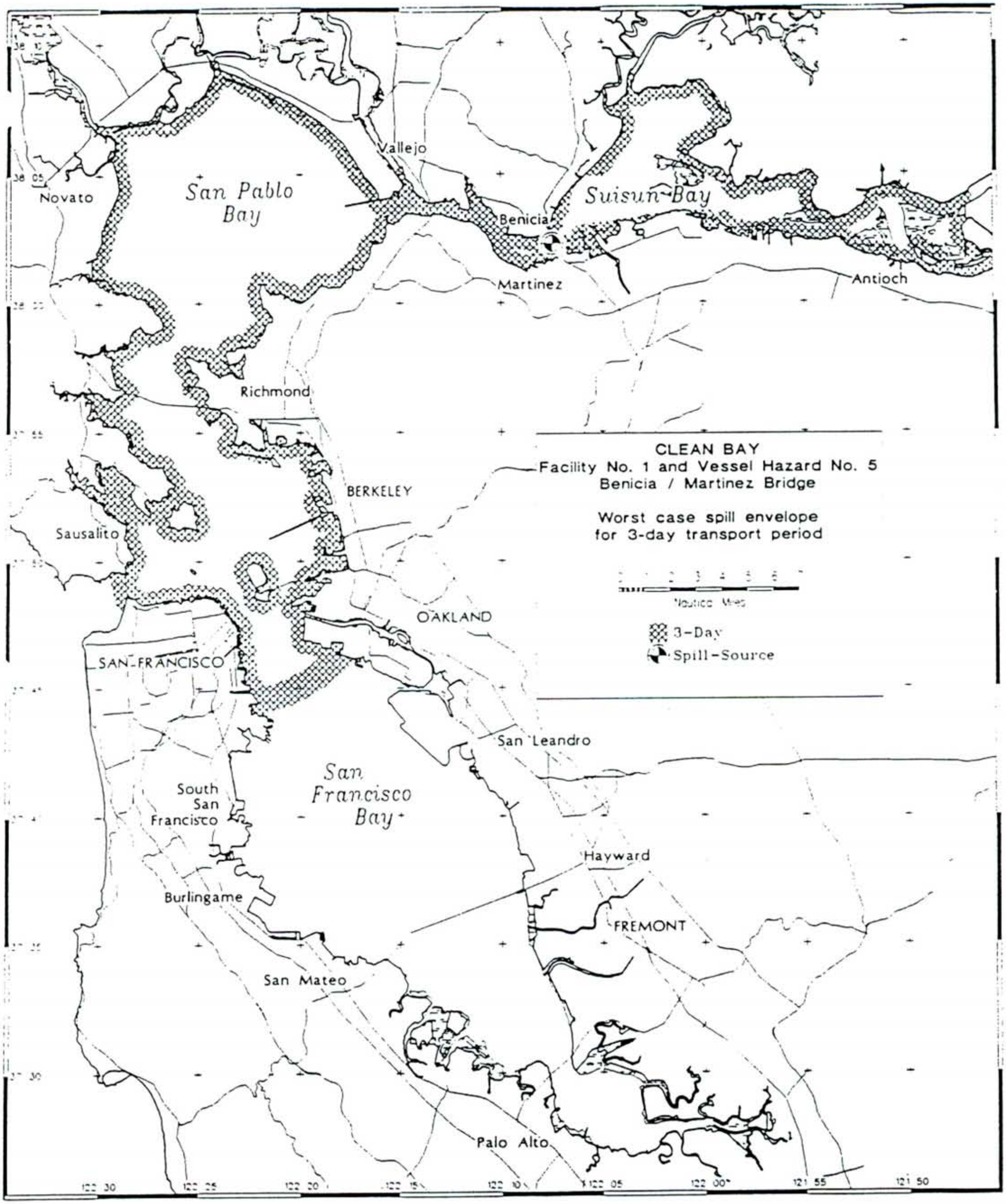
SITE:	Facilities near the Benicia/Martinez Bridge Tosco-Avon Tosco-Amorco Wickland-Martinez terminal Shell Oil wharf Exxon refinery Huntway facility Santa Fe pipeline	LATITUDE:	38-02.5
HAZARD:	Facility	LONGITUDE:	122-07.0
VOLUME:	4,000/ 10,000 bbl		
DURATION:	3 days		

TRAJECTORY ANALYSIS

A spill trajectory envelope was calculated for a cluster of facilities located near the Benicia/Martinez Bridge. The trajectory analysis considered oil transport by the wind, tidal currents, and river flow, and spreading of the oil spill by physical processes such as gravity, surface tension, and tidal dispersion. Spill transport on the flood tide would be expected to move the oil eastward across Suisun Bay. A spill during the ebb tide would be expected to transport the oil westward into San Pablo Bay to approximately Pinole Point. Physical spreading would cause the 4,000 bbl spill to spread across San Pablo Bay approximately 2 miles north of the channel. Spreading of this spill in Suisun Bay would carry the oil to the southern boundary of Grizzly Bay. A 10,000 bbl spill would spread approximately ½ mile farther into San Pablo and Grizzly Bays after 3 days.

Wind-induced surface currents could cause additional transport of oil depending on the direction, strength and persistence of local winds. Northerly winds could transport the oil into San Francisco Bay as far as Oakland Harbor. Oil transported south this way could spread westward to the Golden Gate area. Westerly and southwesterly winds could transport oil on the flood tide across Suisun Bay to the mouths of the San Joaquin and Sacramento Rivers. Transport up these rivers would be limited by the seasonal river flow.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes do not represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-13

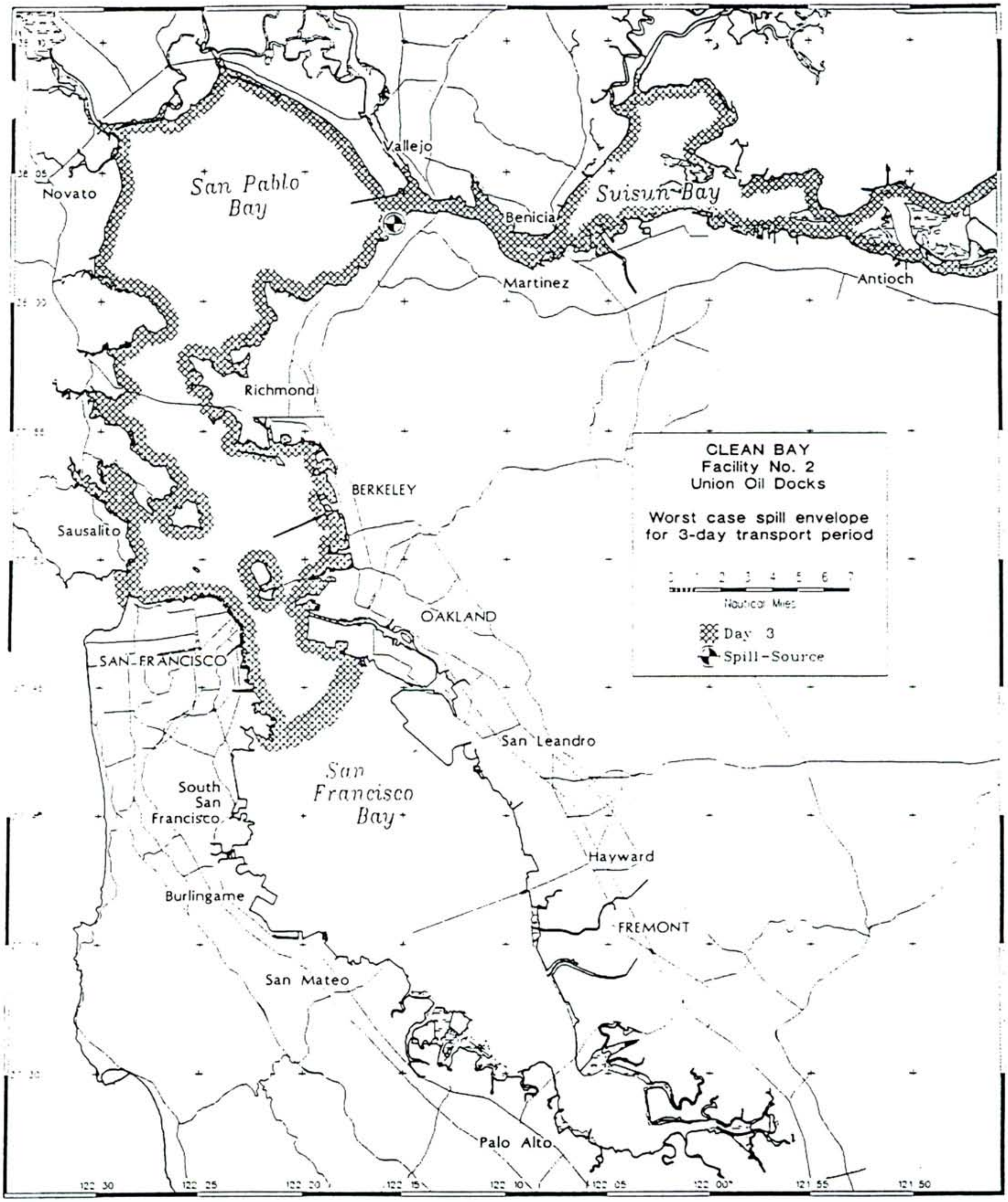
SITE:	Union Oil Docks: Unocal Refinery Wickland Oil (Crockett) Pacific Refinery (Rodeo)	LATITUDE:	38-03.0
HAZARD:	Facility	LONGITUDE:	122-15.5
VOLUME:	10,000 bbl/20,000 bbl		
DURATION:	3 days		

TRAJECTORY ANALYSIS

A spill trajectory envelope was calculated for facilities located immediately west of Carquinez Strait in East San Pablo Bay. Each facility is located on the southern shore near the strait. The analysis considered oil transport by the wind, tidal currents, and river flow, and spreading by physical processes such as gravity, surface tension, and tidal dispersion. Spill transport on the flood tide would move the oil through Carquinez Strait into Suisun Bay. A spill during the ebb tide would be expected to transport the oil westward into San Pablo Bay to approximately Point San Pablo. Physical spreading would cause the 10,000 bbl spill to spread laterally approximately 3 miles across either Suisun Bay or San Pablo Bay. The 20,000 bbl spill would spread approximately ½ mile farther into the bays.

Wind-induced surface currents could cause additional transport of oil depending on the direction, strength, and persistence of local winds. Northerly winds could transport the oil into South San Francisco Bay as far as Hunter Point. Oil transported south could spread westward to the Golden Gate area. Westerly and southwesterly winds could transport the oil across Suisun Bay to the mouths of the San Joaquin and Sacramento Rivers. Transport up these rivers would be limited by seasonal river flow.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes <u>do not</u> represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-15

SITE:	Chevron Refinery	LATITUDE:	37-55.2
HAZARD:	Facility	LONGITUDE:	122-24.5
VOLUME:	30,000 bbl		
DURATION:	3 days		

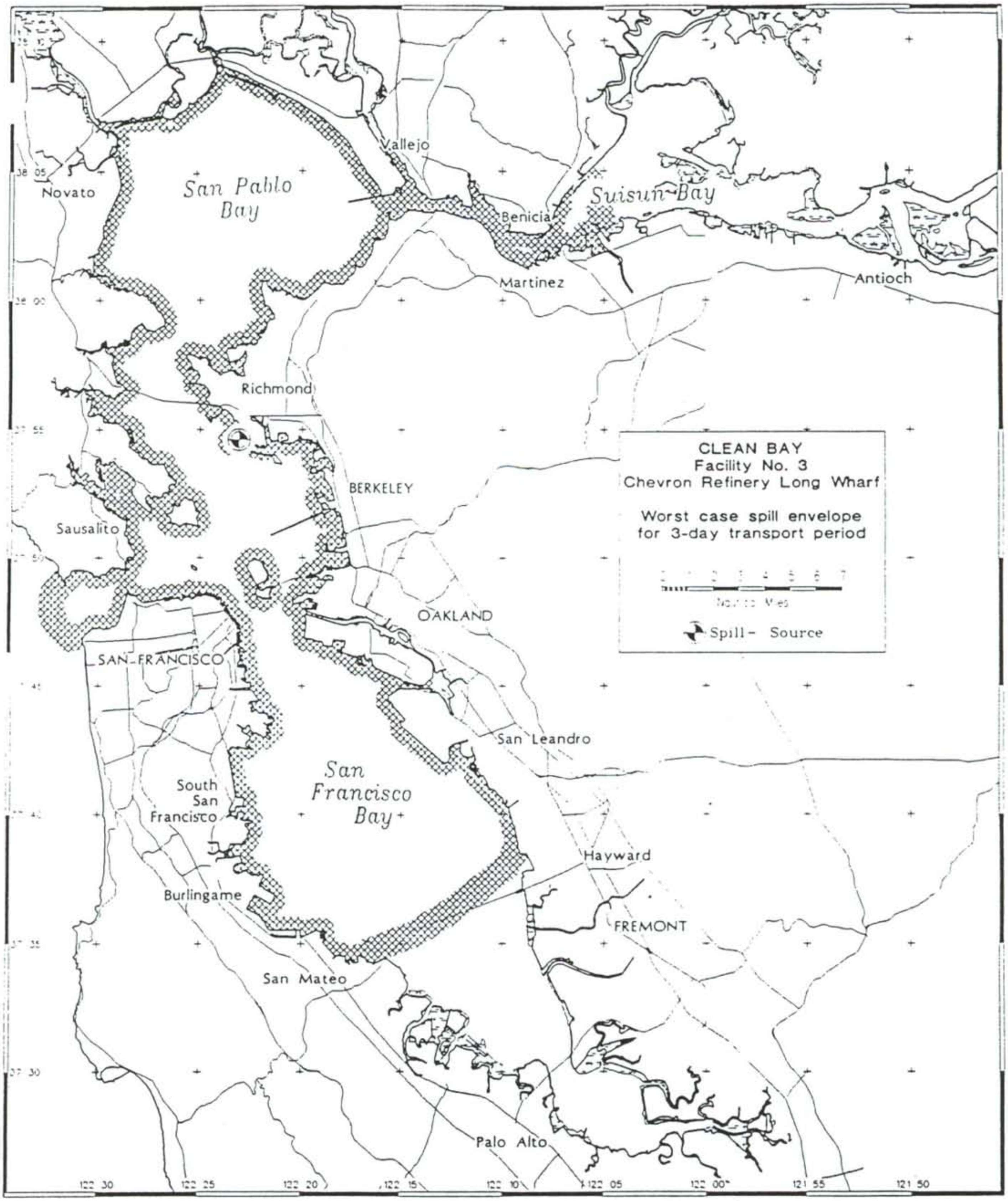
TRAJECTORY ANALYSIS

A spill trajectory envelope was calculated for the Chevron Refinery located on Long Wharf in Richmond. The trajectory analysis considered oil transport by the wind, tidal currents, and river flows, and spreading of the oil spill by physical processes such as gravity, surface tension, and tidal dispersion. Spill transport on a flood tide would be expected to transport the oil northward into San Pablo Bay and then eastward towards the Carquinez Strait. A spill during an ebbing tide would be expected to transport the oil south and west as far as the Golden Gate area. Spreading of the spill over 3 days would move the limit of the spill out of San Francisco Bay.

Wind-induced surface currents could cause additional transport of oil depending on the direction, strength, and persistence of local winds. Northerly winds could transport the oil into South San Francisco Bay as far as the San Mateo Bridge. Within 3 days, westerly and as southwesterly winds would carry oil across San Pablo Bay and through the Carquinez Strait to approximately 3 miles east of the Benicia/Martinez Bridge.

Any oil exiting San Francisco Bay could be expected to be transported either southward or northward depending on the direction of the wind. For oil that is transported outside the Bay, northerly winds would move the oil as far as Point Montara after 3 days. Southerly winds outside the Bay would move the oil northward as far as Point Reyes after 3 days.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes <u>do not</u> represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-17

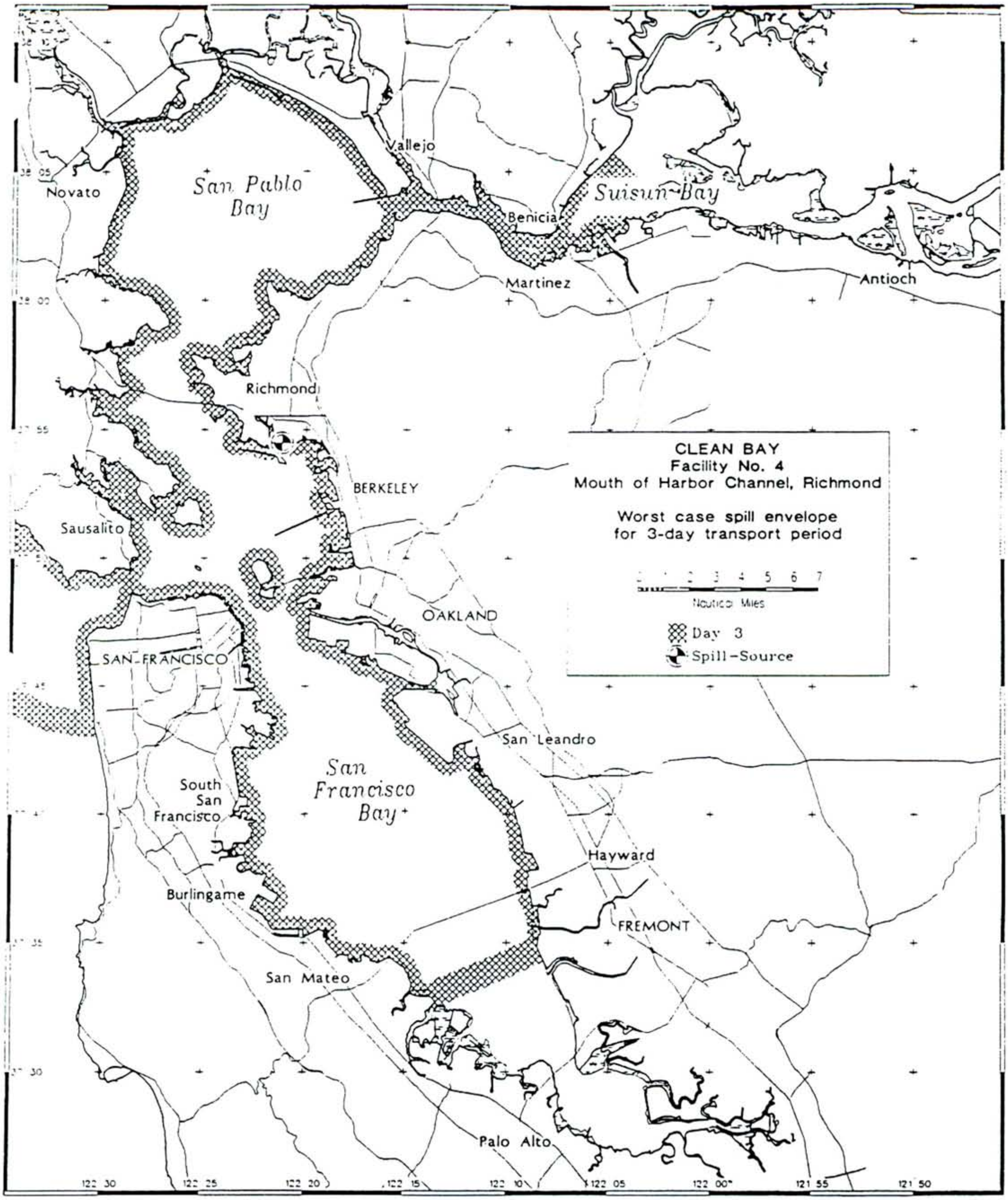
SITE:	Mouth of Harbor Channel, Richmond Unocal Arco Time Oil GATX Castrol Texaco	LATITUDE:	37-54.9
HAZARD:	Facility	LONGITUDE:	122-21.5
VOLUME:	800/3,800 bbl		
DURATION:	3 days		

TRAJECTORY ANALYSIS:

A spill trajectory envelope was calculated for several facilities located at the mouth of Harbor Channel in Richmond. The trajectory analysis predicted the movement and spreading of a spill released into the water near the shoreline at the northern end of the harbor channel in Richmond. The analysis considered oil transport by the wind and tidal currents, and spreading of the oil spill by physical processes such as gravity, surface tension, and tidal dispersion. Spill transport on an ebbing tide would be expected to move the oil from the harbor mouth at Richmond through the Golden Gate and out of San Francisco Bay. A spill during the flood tide would be expected to transport the oil into San Pablo Bay. During this time physical spreading of an 800 bbl spill would cause the spilled material (in this vegetable oil) to be moved northward approximately 2 miles into San Pablo Bay or westward from the Golden Gate. Spreading of the larger 3,800 bbl spill over 3 days could transport the oil approximately 2 miles farther.

Wind-induced surface currents could cause additional transport of oil depending on the direction, strength, and persistence of local winds. Northerly winds, combined with physical spreading, could transport the oil southward into South San Francisco Bay as far as the San Mateo Bridge. Within 3 days, westerly and southwesterly winds could move the oil across San Pablo Bay and through the Carquinez Straits and approximately 5 miles eastward into Suisun Bay. Because of the relatively small size of the spills from these facilities, no significant amounts of oil are expected to be transported outside of San Francisco Bay.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes <u>do not</u> represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-19

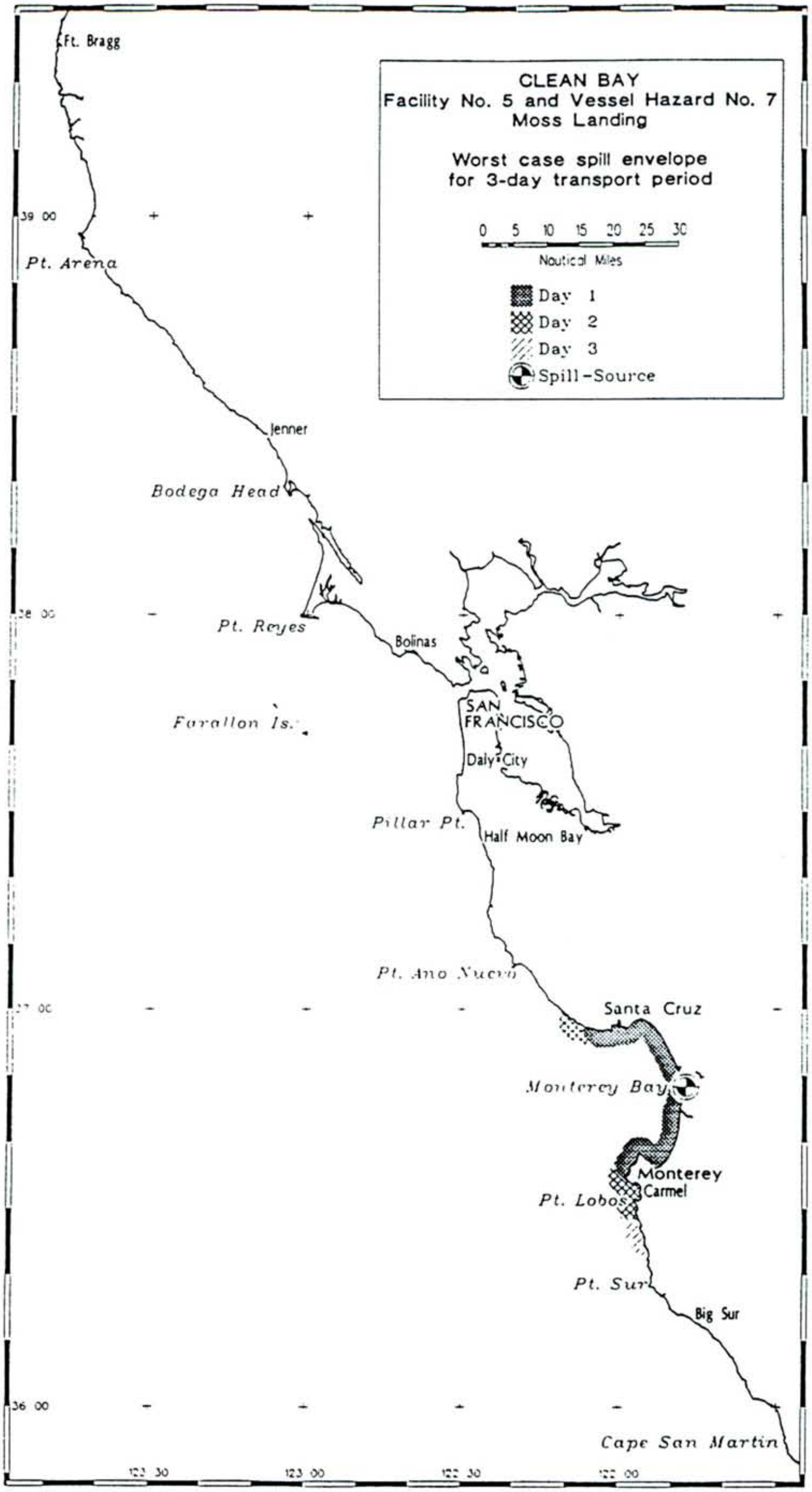
SITE:	Moss Landing	LATITUDE:	36-47.7
HAZARD:	Facility	LONGITUDE:	121-47.0
VOLUME:	9,000 bbl		
DURATION:	3 days		

TRAJECTORY ANALYSIS

A spill trajectory envelope was calculated for a shoreline spill at Moss Landing, which is located in central Monterey Bay approximately three miles north of the Salinas River. The trajectory analysis considered oil transport by the wind and tidal currents, and spreading of the oil spill by physical processes such as gravity, surface tension, and tidal dispersion. Spill transport on an ebbing tide would be expected to move the oil from the landing approximately 4 miles to the southwest towards Point Pinos. Tidal action during the flood tide would be expected to transport a spill a similar distance to the north. Spreading of the spill would be expected to increase the size of the spill by a similar magnitude over the 3-day time period. Based on this analysis, spreading and tidal transport without additional wind driven transport would not be expected to move the spill out of Monterey Bay within 3 days.

Wind induced surface currents would cause additional transport of oil depending on the direction, strength and persistence of local winds. Certain wind conditions could allow the spill to be transported to the north or south along the coast outside of Monterey Bay. Easterly winds could move the spill as far as 10 miles offshore over a 3-day time period. When combined with the spreading effects of tidal action and mechanical spreading, north-northwesterly winds could move the spill down the coast as far as Point Sur. Likewise, south-south-easterly winds could move the oil up the coast towards San Francisco to within 3 miles of Point Ano Nuevo.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes do not represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-21

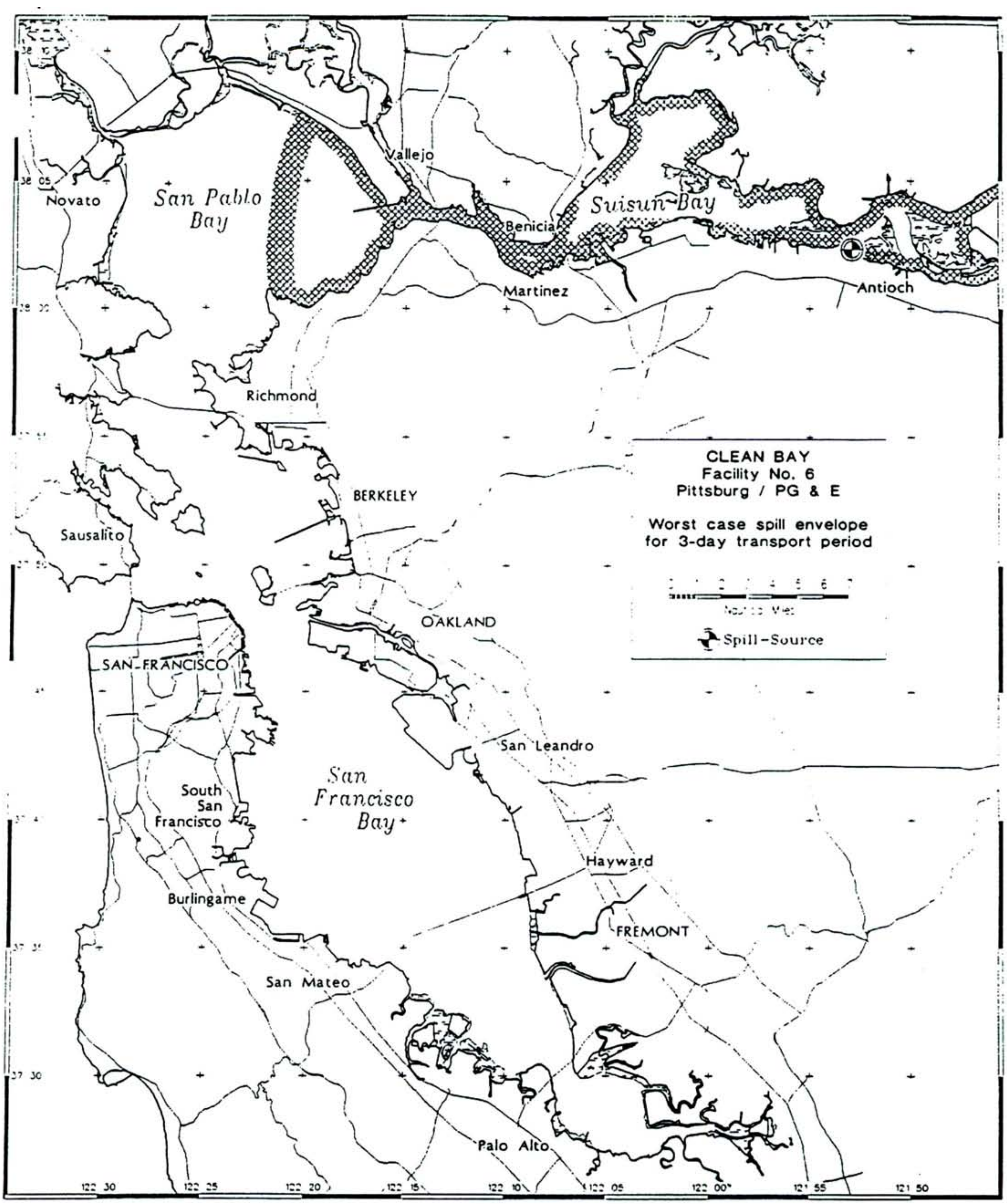
SITE:	Pittsburg (PG&E)	LATITUDE:	38-02.4'
HAZARD:	Facility	LONGITUDE:	122-53.6'
VOLUME:	10,000 bbl		
DURATION:	3 days		

TRAJECTORY ANALYSIS

A spill trajectory envelope was calculated for the PG&E facility located on the south shore of Suisun Bay in Pittsburg. The trajectory analysis considered oil transport by the wind, tidal currents, and river flow, and spreading of the oil spill by physical processes such as gravity, surface tension, and tidal dispersion. Spill transport on the flood tide would be expected to transport the oil eastward from Suisun Bay approximately 5 miles from the spill location. A spill during the ebb tide would be expected to transport the oil westward across Suisun Bay approximately 5 miles from the spill location. Physical spreading of a 10,000 bbl spill would cause additional transport of approximately 3 miles after 3 days.

Wind-induced surface currents could cause additional transport of oil depending on the direction, strength, and persistence of local winds. Easterly winds could transport the oil across Suisun Bay to the Carquinez Strait. Westerly and southwesterly winds could transport the oil towards the San Joaquin and Sacramento Rivers. Transport up these rivers would be limited by seasonal river flow.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes do not represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-23

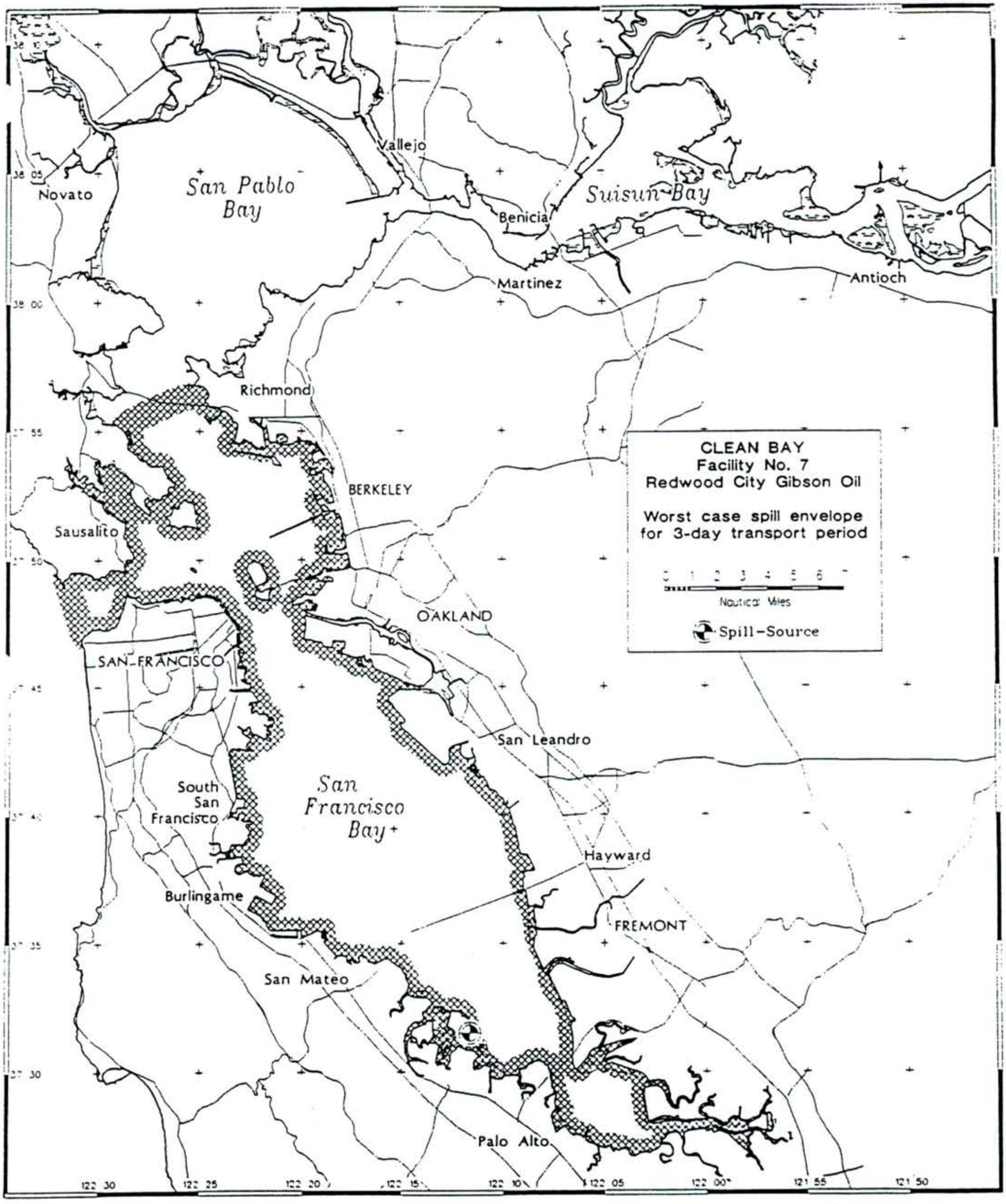
SITE:	Redwood City Gibson Oil	LATITUDE:	37-31'
HAZARD:	Facility	LONGITUDE:	122-12'
VOLUME:	2,000 bbl		
DURATION:	3 days		

TRAJECTORY ANALYSIS

A spill trajectory envelope was calculated for one facility located on the western shore of south San Francisco Bay in Redwood City. The trajectory analysis predicted the movement and spreading of a spill released into the water from the shoreline facility. The trajectory analysis considered oil transport by the wind and tidal currents, and spreading of the oil spill by physical processes such as gravity, surface tension, and tidal dispersion.

Spill transport on a flood tide combined with spreading and northerly winds could carry the spill southward to the southern shore of San Francisco Bay within the 3-day time period. A spill during the ebbing tide would be transported by tidal action approximately 2 miles north of the San Mateo Bridge. Further movement to the north would occur by physical spreading and by wind drift during southerly winds. These two processes would be expected to carry the spill as far north as Richmond during the 3-day time period. Spreading and tidal dispersion would also be expected to carry the spill through the Golden Gate over 3 days.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes <u>do not</u> represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-25

SITE:	San Francisco - Pier 70 PG&E	LATITUDE:	37-46.0
HAZARD:	Facility	LONGITUDE:	122-22.9
VOLUME:	50,000 bbl		
DURATION:	3 days		

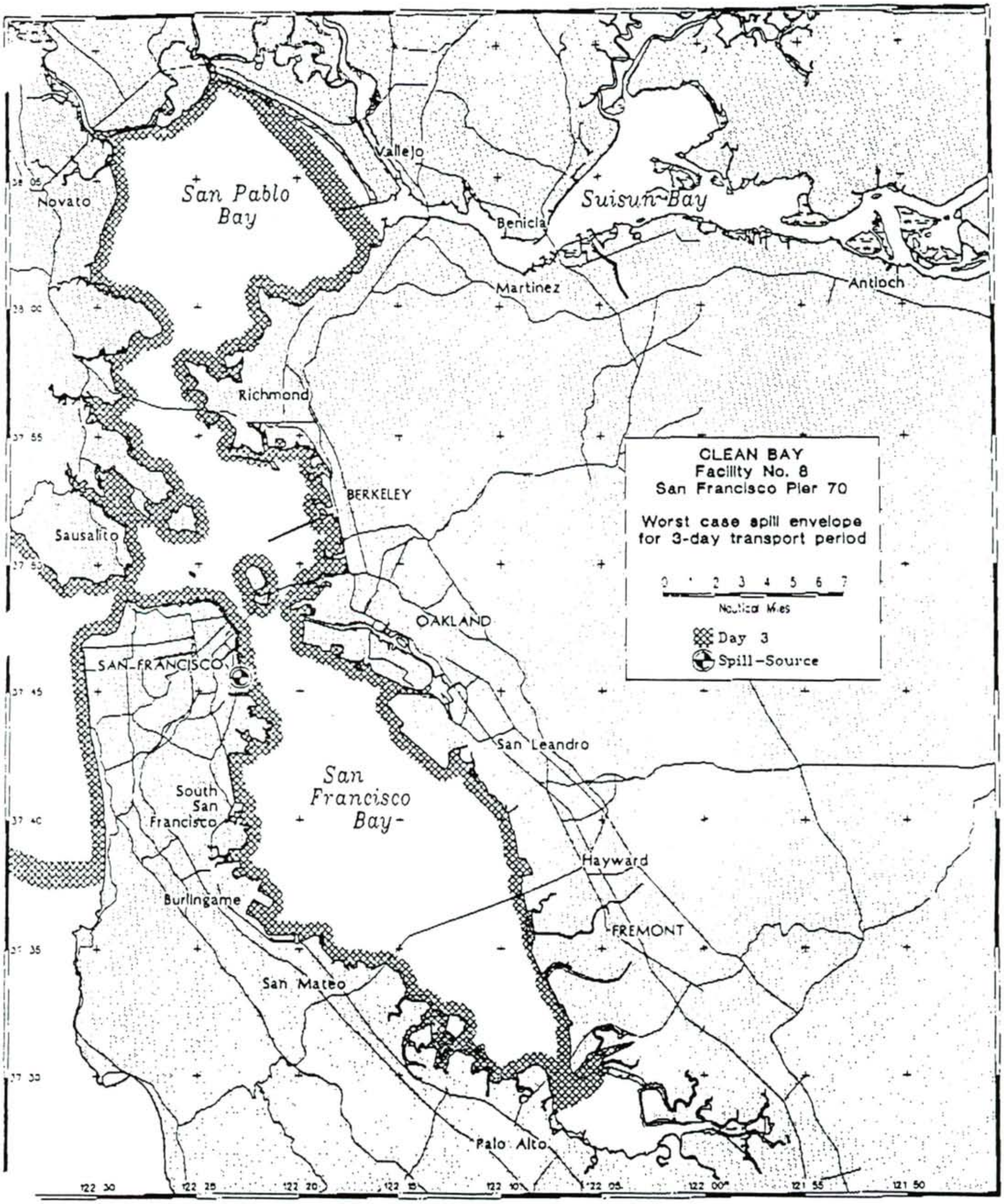
TRAJECTORY ANALYSIS

A spill trajectory envelope was calculated for the PG&E facility located at Pier 70 in San Francisco. The facility is located approximately one mile south of the San Francisco Bay Bridge. The analysis considered oil transport by the wind and tidal currents, and spreading of the oil spill by physical processes such as gravity, surface tension, and tidal dispersion. Spill transport on an ebbing tide would be expected to move the oil northward to and through the Golden Gate and out of San Francisco Bay. During this time physical spreading of a 50,000 bbl spill would carry the oil northward within San Francisco Bay to the Richmond area. A spill during the flood tide, when combined with physical spreading, would be expected to transport the oil southward into South San Francisco Bay as far Point San Bruno.

Wind-induced surface currents could cause additional transport of oil depending on the direction, strength, and persistence of local winds. Northerly winds, combined with physical spreading, could transport the oil into south San Francisco Bay as far as the San Mateo Bridge.

Any oil exiting San Francisco Bay would be expected to be transported either southward or northward depending on the direction of the wind. For oil that is transported outside the Bay, northerly winds could transport the oil as far as Point Montara after 3 days. Southerly winds outside the Bay could transport the oil northward as far as Point Reyes after 3 days.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes <u>do not</u> represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-27

SITE:	Harding Rock	LATITUDE:	37-46.0
HAZARD:	Vessel Navigation	LONGITUDE:	122-22.9
VOLUME:	300,000 bbl		
DURATION:	3 days		

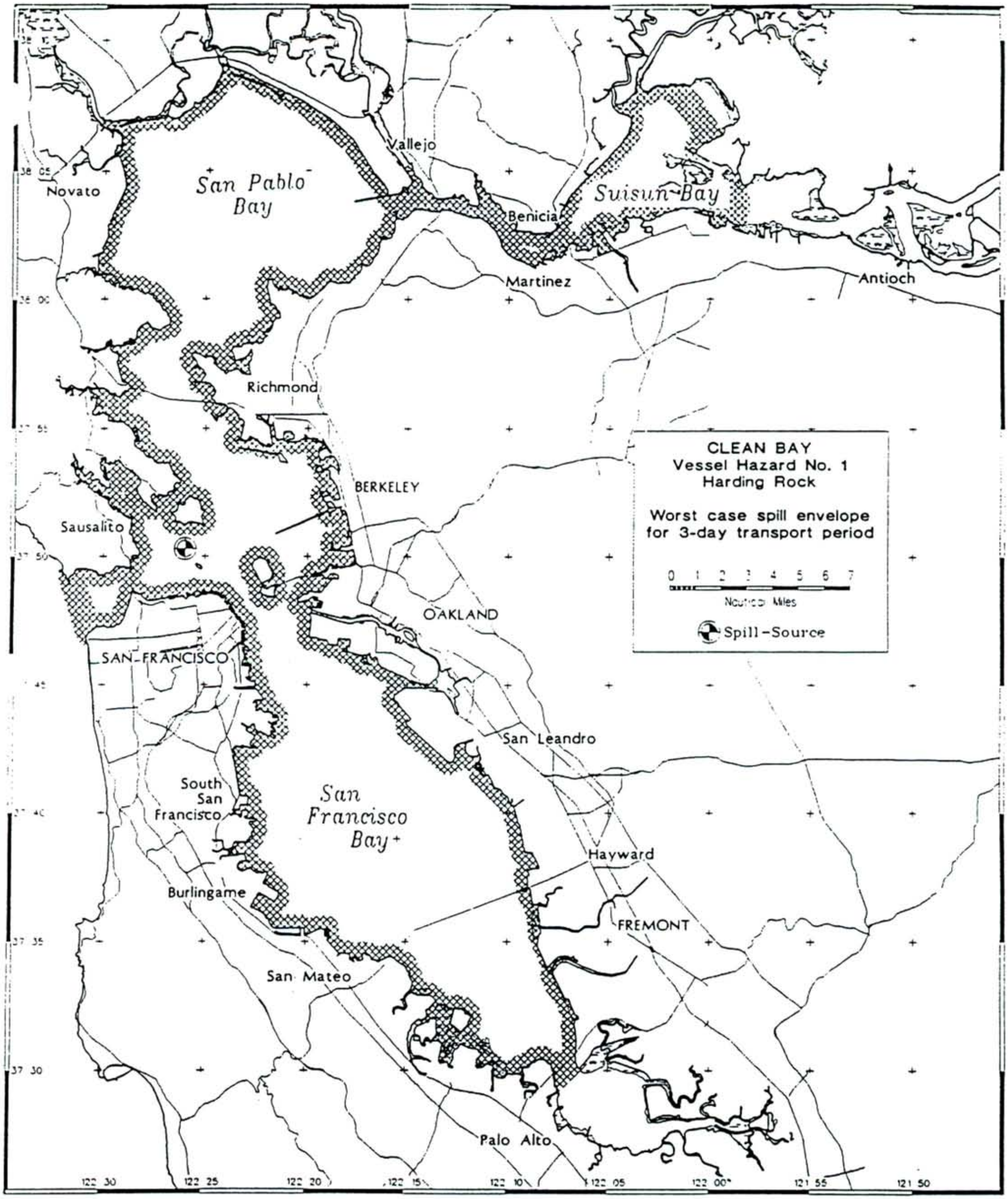
TRAJECTORY ANALYSIS

A spill trajectory envelope was calculated for vessel navigation hazards near Harding Rock in San Francisco Bay, just east of the Golden Gate. The trajectory analysis considered oil transport by the wind and tidal currents, and spreading of the oil spill by physical processes such as gravity, surface tension, and tidal dispersion. Spill transport on an ebbing tide would carry the oil westward through the Golden Gate. At that point, ebb tides would likely spread the oil northward and southward. A spill during the flood tide would transport the oil northward and southward farther into San Francisco Bay. A spill transported over the entire flood tide would reach the Richmond/San Rafael Bridge to the north and Hunters Point to the south. Physical spreading of the spill over the initial 6-hour time period would move the oil an additional 2 miles.

Wind-induced surface currents could cause additional transport of oil depending on the direction, strength, and persistence of local winds. Northerly winds, combined with physical spreading, could transport the oil into south San Francisco Bay past the San Mateo Bridge. Within 3 days, westerly and southwesterly winds could carry oil across San Pablo Bay to approximately the Carquinez Bridge.

Any oil exiting San Francisco Bay would be expected to be transported either southward or northward along the coast depending on the direction of the wind. For oil that is transported outside the Bay, northerly winds could transport the oil as far as Point Montara after 3 days. Southerly winds outside the Bay could transport the oil northward as far as Point Reyes after 3 days.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes do not represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-29

SITE:	Anchorage #9	LATITUDE:	37-46.0
HAZARD:	Vessel Navigation	LONGITUDE:	122-22.9
VOLUME:	300,000 bbl		
DURATION:	3 days		

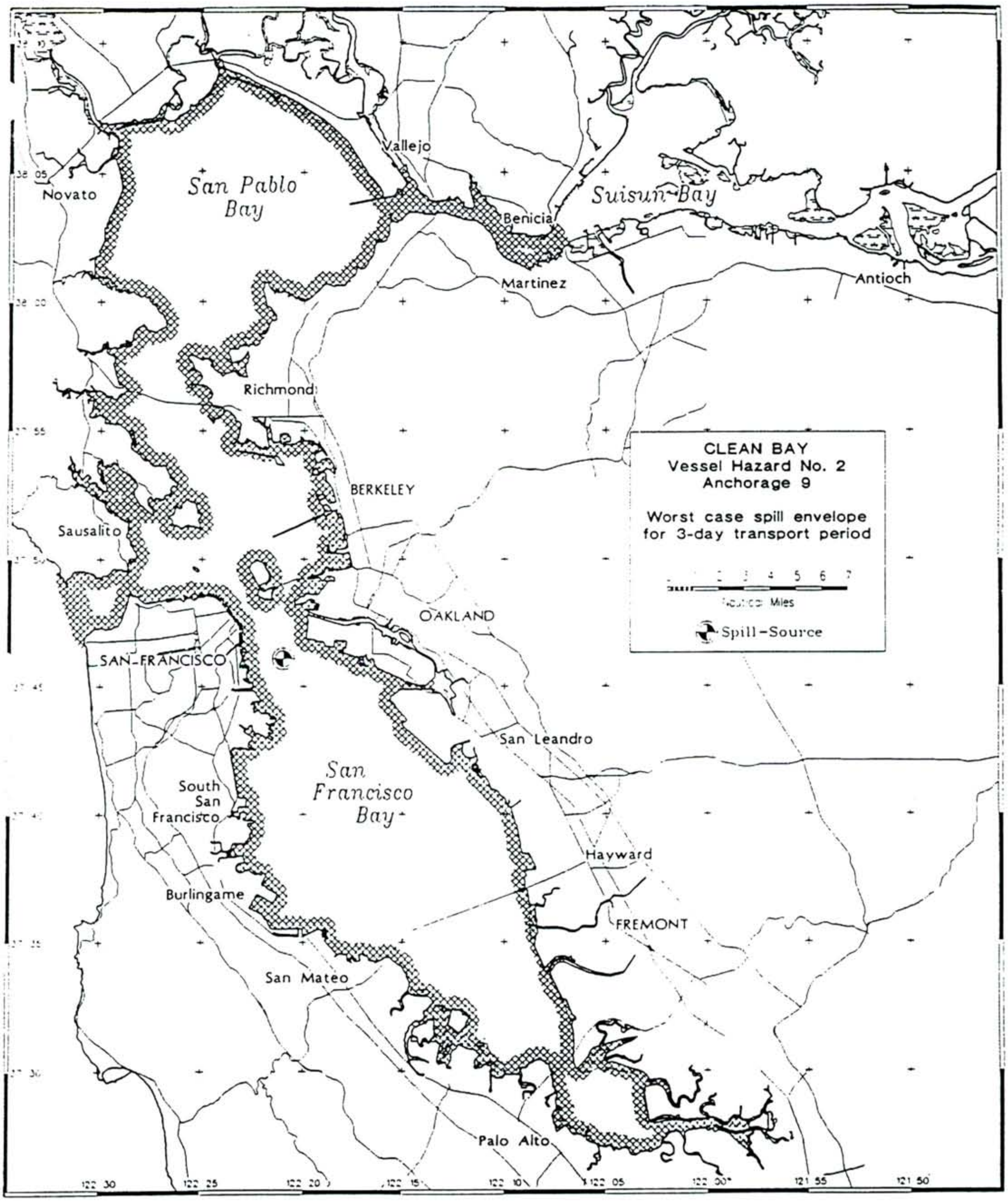
TRAJECTORY ANALYSIS

A spill trajectory envelope was calculated for vessel navigation hazards near Anchorage #9 in central San Francisco Bay. The trajectory analysis considered oil transport by the wind and tidal currents, and spreading of the oil spill by physical processes such as gravity, surface tension, and tidal dispersion. Spill transport on an ebbing tide could carry the oil westward through the Golden Gate. At that point, winds could likely spread the oil northward or southward. A spill during the flood tide could transport the oil northward and southward within San Francisco Bay. A spill transported over the entire flood tide would reach the Richmond/San Rafael Bridge to the north and Hunters Point to the south. Physical spreading of the spill over the initial 6-hour time period could transport the oil an additional 2 miles.

Wind-induced surface currents could cause additional transport of oil depending on the direction, strength, and persistence of local winds. Northerly winds, combined with physical spreading, could transport the oil into South San Francisco Bay past the San Mateo Bridge. Within 3 days, westerly and as southwesterly winds could carry oil across San Pablo Bay to approximately the Carquinez Bridge.

Any oil exiting San Francisco Bay would be expected to be transported either southward or northward along the coast depending on the direction of the wind. For oil that is transported outside the Bay, northerly winds could transport the oil as far as Point Montara after 3 days. Southerly winds outside the Bay could transport the oil northward as far as Point Reyes after 3 days.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes <u>do not</u> represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-31

SITE:	Richmond/San Rafael Bridge	LATITUDE:	37-57'
HAZARD:	Vessel Navigation	LONGITUDE:	122-27'
VOLUME:	143,750 bbl		
DURATION:	3 days		

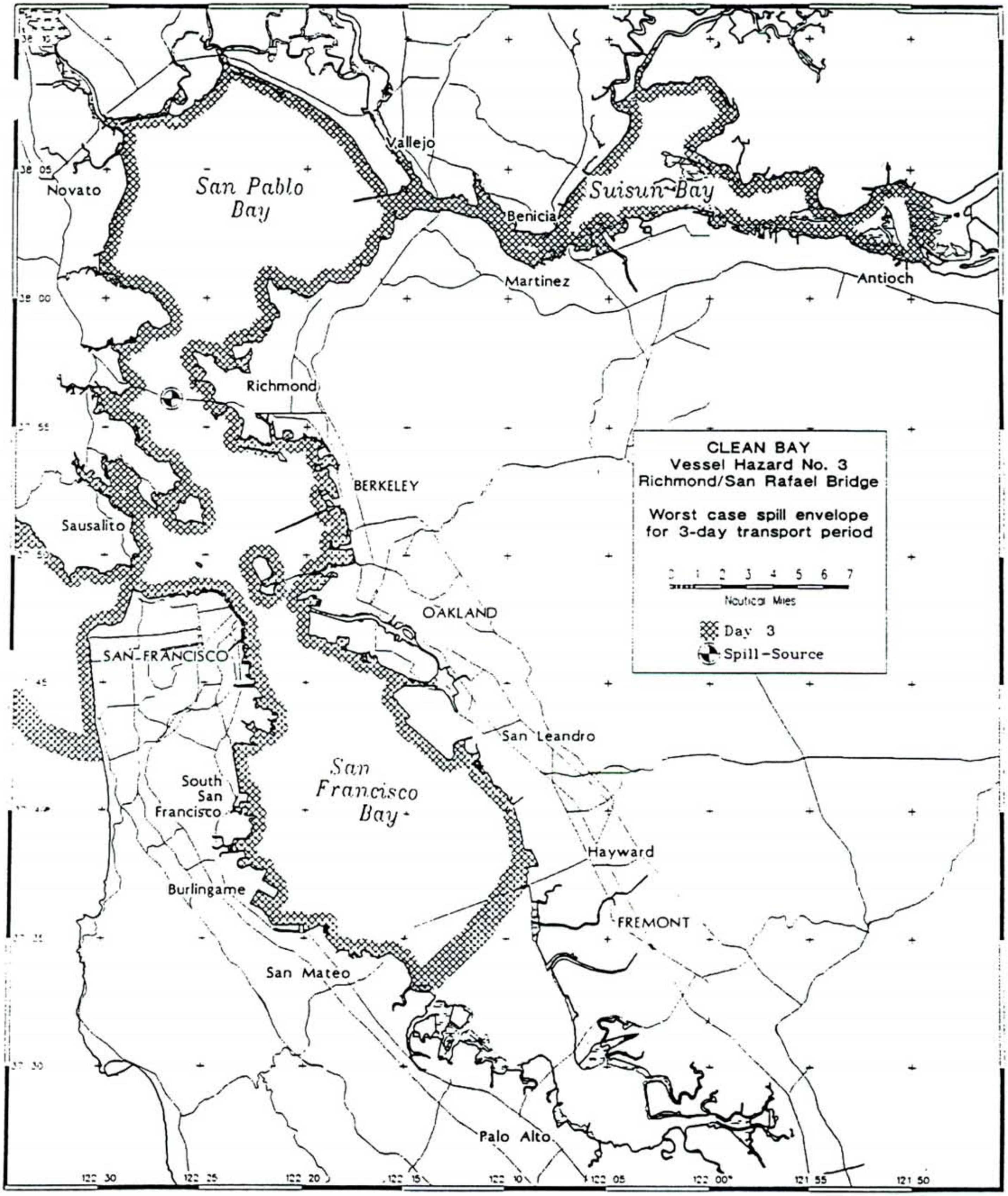
TRAJECTORY ANALYSIS

A spill trajectory envelope was calculated for the vessel navigation hazard area near the Richmond/San Rafael Bridge located west of Richmond. The trajectory analysis considered oil transport by the wind, tidal currents, and river flows, and spreading of the oil spill by physical processes such as gravity, surface tension, and tidal dispersion. Spill transport on a flood tide would be expected to move the oil northward into San Pablo Bay and then eastward through the Carquinez Straits. An ebb tide would be expected to transport the oil south and west as far as the Golden Gate area. Spreading of the 143,750 bbl spill over 3 days would likely transport the limit of the spill out of San Francisco Bay.

Wind-induced surface currents could cause additional transport of oil depending on the direction, strength, and persistence of local winds. Northerly winds could transport the oil into South San Francisco Bay as far as the San Mateo Bridge. Within 3 days, westerly and as southwesterly winds would carry oil across Suisun Bay approximately to Pittsburg.

Any oil exiting San Francisco Bay would be expected to be transported either southward or northward along the coast depending on the direction of the wind. For oil that is transported outside the Bay, northerly winds could transport the oil as far as Point Montara after 3 days. Southerly winds outside the Bay could transport the oil northward as far as Point Reyes after 3 days.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes do not represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-33

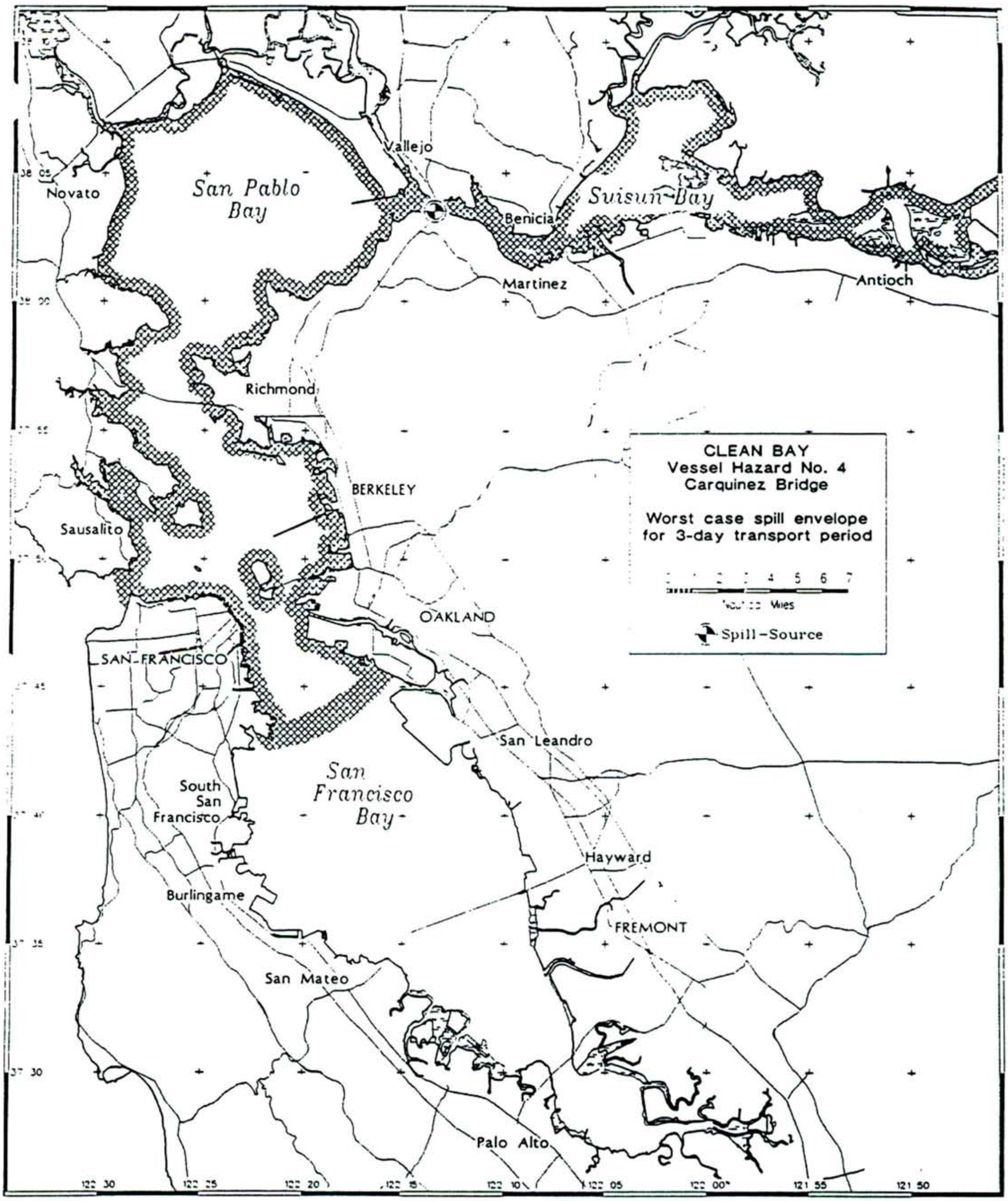
SITE:	Carquinez Bridge	LATITUDE:	38-03.0
HAZARD:	Vessel Navigation	LONGITUDE:	122-15.5
VOLUME:	143,750 bbl		
DURATION:	3 days		

TRAJECTORY ANALYSIS

A spill trajectory envelope was calculated for the Carquinez Bridge vessel navigation hazard area. The trajectory analysis considered oil transport by the wind, tidal currents, and river flow, and spreading of the oil spill by physical processes such as gravity, surface tension, and tidal dispersion. Spill transport on the flood tide would be expected to move the oil eastward across Suisun Bay. A spill during the ebb tide might be expected to transport the oil westward into San Pablo Bay to approximately Pinole Point. Physical spreading could cause the 143,750 bbl spill to spread completely across San Pablo Bay within 3 days. Spreading of this spill in Suisun Bay could carry the oil across to Grizzly Bay and Honker Bay.

Wind-induced surface currents could cause additional transport of oil depending on the direction, strength, and persistence of local winds. Northerly winds could transport the oil into San Francisco Bay as far as Oakland Harbor. Oil transported south this way could spread westward to the Golden Gate area. Westerly and southwesterly winds could transport oil on the flood tide across Suisun Bay to the mouths of the San Joaquin and Sacramento Rivers. Transport up these rivers would be limited by seasonal river flows.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes do not represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-35

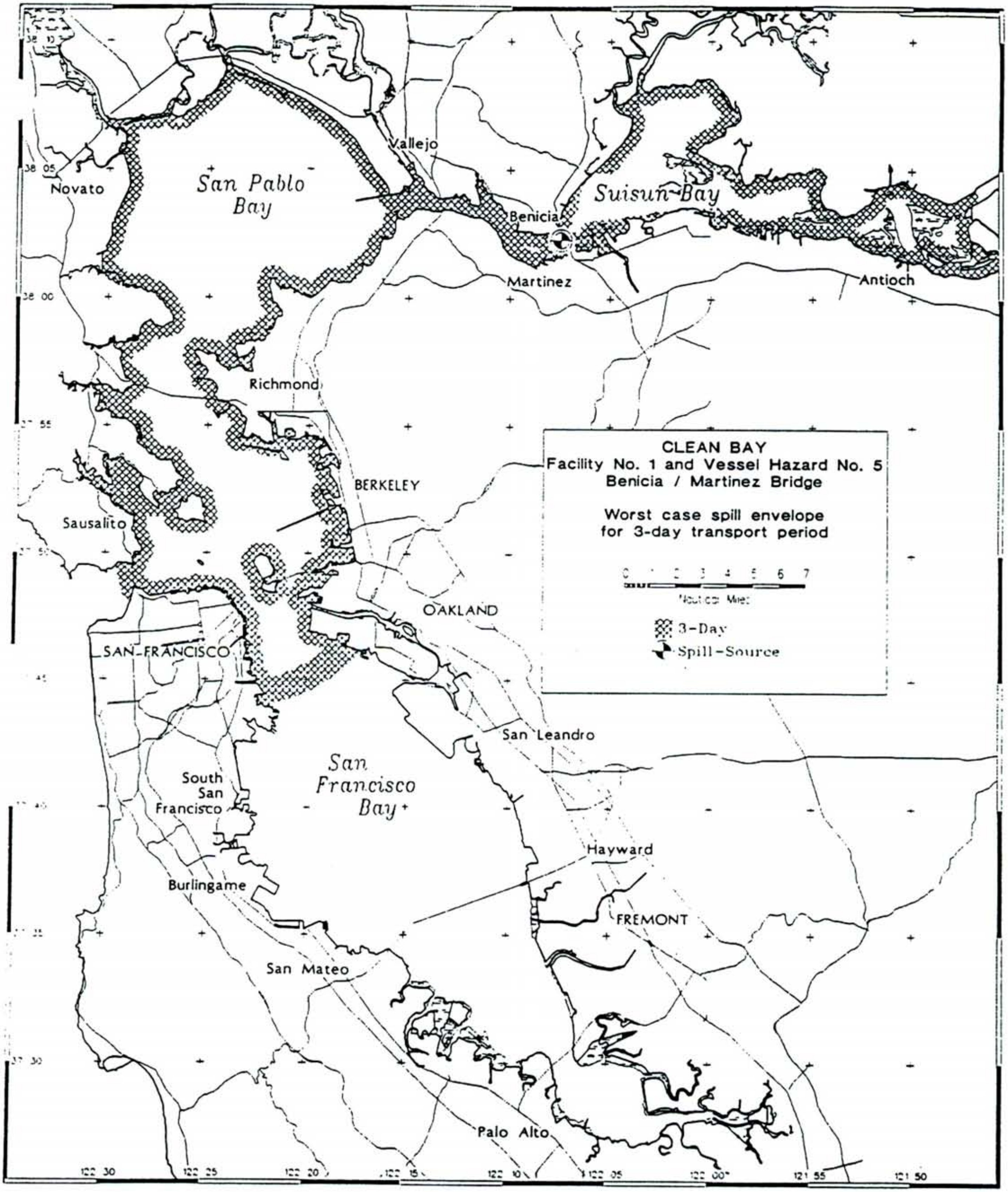
SITE:	Benicia/Martinez Bridge	LATITUDE:	38-02.5
HAZARD:	Vessel Navigation	LONGITUDE:	122-07.0
VOLUME:	143,750 bbl		
DURATION:	3 days		

TRAJECTORY ANALYSIS

A spill trajectory envelope was calculated for the Benicia/Martinez Bridge vessel hazard area. The trajectory analysis considered oil transport by the wind, tidal currents, and river flow, and spreading of the oil spill by physical processes such as gravity, surface tension, and tidal dispersion. Spill transport on the flood tide would be expected to transport the oil eastward across Suisun Bay. A spill during the ebb tide would be expected to transport the oil westward into San Pablo Bay to approximately Pinole Point. Physical spreading of a 143,750 bbl spill could cause the oil to spread completely across San Pablo Bay. Spreading of this spill in Suisun Bay would carry the oil across Grizzly and Honker Bays.

Wind-induced surface currents could cause additional transport of oil depending on the direction, strength, and persistence of local winds. Northerly winds could transport the oil into San Francisco Bay as far as the West Oakland area. Oil transported south could spread westward to the Golden Gate area. Westerly and southwesterly winds could transport the oil on the flood tide across Suisun Bay to the mouths of the San Joaquin and Sacramento Rivers. Transport up these rivers would be limited by seasonal river flows.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes do not represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-37

SITE:	Precautionary Area Outside San Francisco Bay	LATITUDE:	37-46.0
HAZARD:	Vessel Navigation	LONGITUDE:	122-22.9
VOLUME:	300,000 bbl		
DURATION:	3 days		

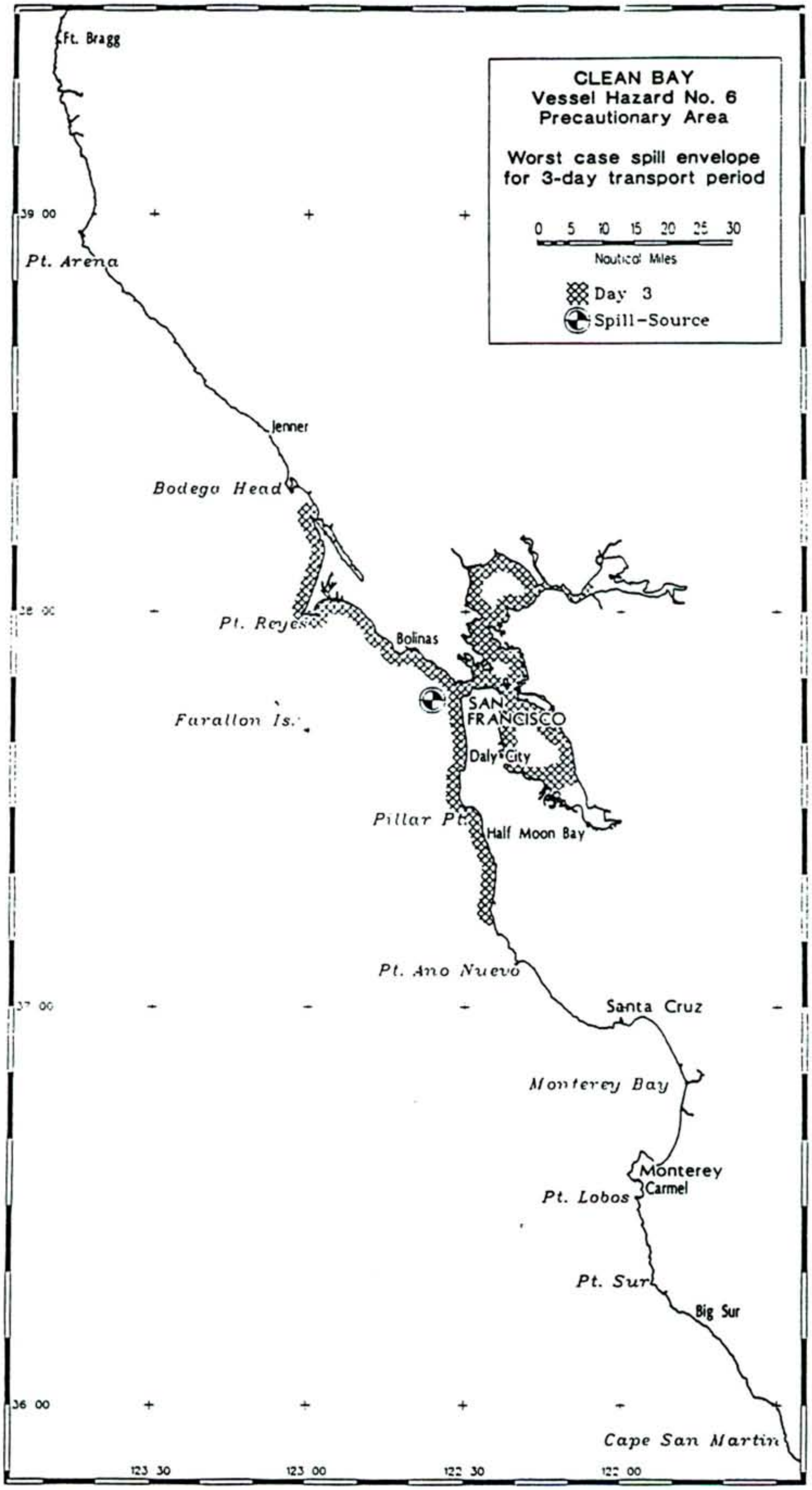
TRAJECTORY ANALYSIS

A spill trajectory envelope was calculated for the vessel navigation hazard area just outside of San Francisco Bay. The trajectory analysis considered oil transport by the wind and tidal currents, and spreading of the oil spill by physical processes such as gravity, surface tension, and tidal dispersion. Spill transport occurring on an ebbing tide would transport the oil away from the Precautionary Area to the north, south, and west. A spill during the flood tide would transport the oil through the Golden Gate and northward and southward within San Francisco Bay. A spill occurring over the entire flood tide would reach Richmond Harbor to the north and to Oakland Harbor to the south. Physical spreading of the spill over the initial 6-hour time period would move the oil an additional 2 miles.

Wind-induced surface currents could cause additional transport of oil depending on the direction, strength, and persistence of local winds. Northerly winds, combined with physical spreading, could transport the oil into South San Francisco Bay past the San Mateo Bridge. Within 3 days, westerly and southwesterly winds could carry oil across San Pablo Bay to approximately the Carquinez Bridge.

Oil not entering San Francisco Bay would be expected to be transported either southward or northward along the coast depending on the direction of the wind. For oil that is transported outside the Bay, northerly winds could transport the oil as far as Point Montara after 3 days. Southerly winds outside the Bay could transport the oil northward as far as Point Reyes after 3 days.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes <u>do not</u> represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-39

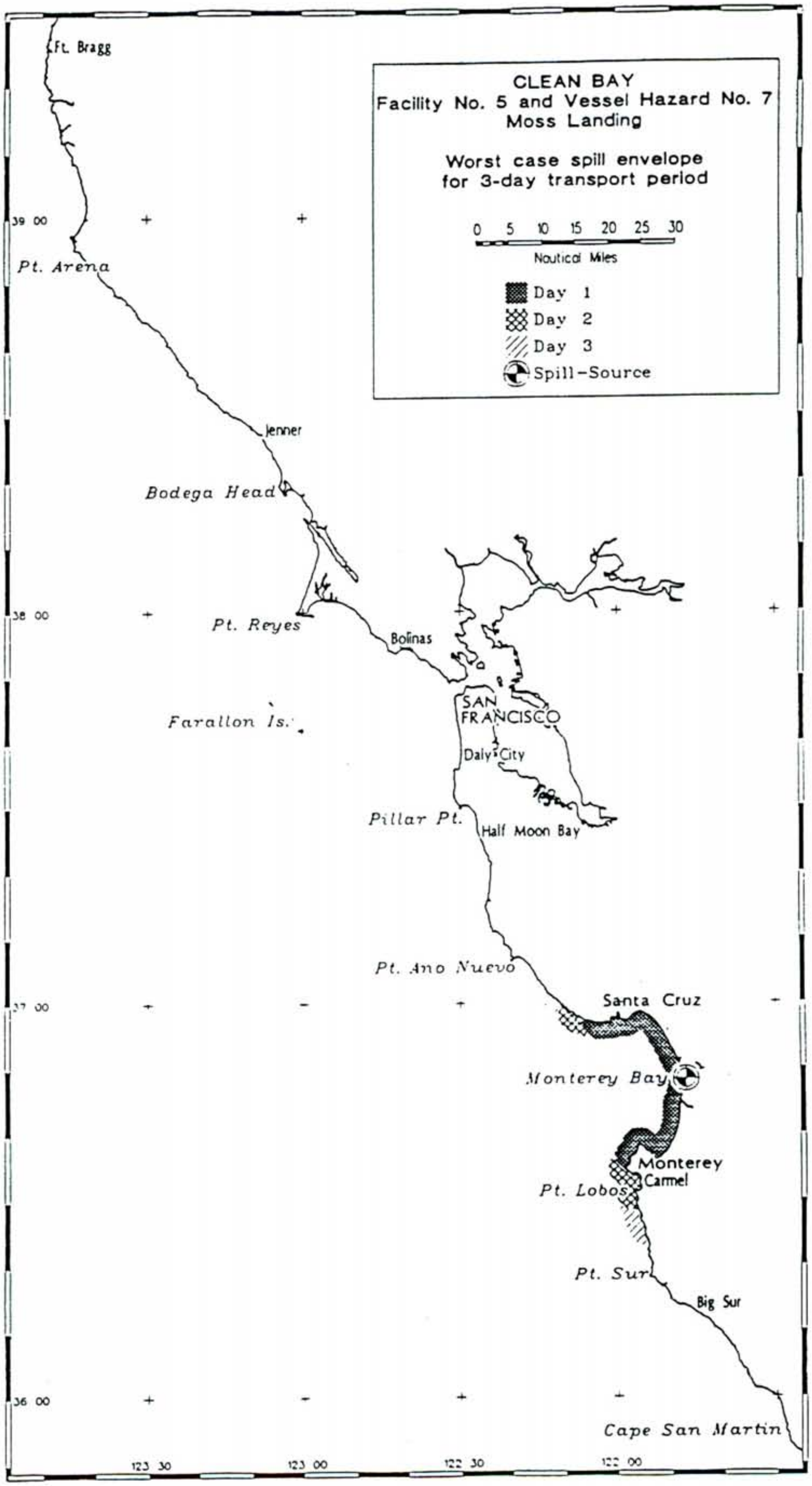
SITE:	Moss Landing	LATITUDE:	36-47.7
HAZARD:	Vessel Navigation	LONGITUDE:	121-47.0
VOLUME:	87,500 bbl		
DURATION:	3 days		

TRAJECTORY ANALYSIS

A spill trajectory envelope was calculated for the vessel hazard area at Moss Landing, which is located in central Monterey Bay approximately three miles north of the Salinas River. The trajectory analysis considered oil transport by the wind and tidal currents, and spreading of the oil spill by physical processes such as gravity, surface tension, and tidal dispersion. Spill transport on an ebbing tide would be expected to move the oil from the landing approximately 4 miles to the southwest towards Point Pinos. Tidal action during the flood tide would be expected to transport a spill a similar distance to the north. Spreading of the spill would be expected to increase the size of the spill by a similar magnitude over the 10-day time period. Based on this analysis, spreading and tidal transport without additional wind driven transport would not be expected to move the spill out of Monterey Bay within 3 days.

Wind-induced surface currents could cause additional transport of oil depending on the direction, strength and persistence of local winds. Certain wind conditions could allow the spill to be transported to the north or south along the coast outside of Monterey Bay. Easterly winds could transport the spill as far as 10 miles offshore over a 3-day time period. When combined with the spreading effects of tidal action and mechanical spreading, north-northwesterly winds could transport the spill down the coast as far as Point Sur. Likewise, south-south-easterly winds could move the oil up the coast towards San Francisco to within 3 miles of Point Ano Nuevo.

These spill trajectory envelopes represent the outer perimeter of shoreside areas that could receive oil in the event of any spill. The envelopes are based on regional extremes of climate, tide, current, and wind and assume pessimistic dispersion and other adverse weather conditions. These trajectory envelopes do not represent the trajectory of any one spill. A full discussion of the details used for preparing these spill envelopes is provided in Section 202.2.



1688-001-820

202-41

This page intentionally left blank.